BULLETIN No. 55

SAN DIEGUITO

AND

SAN DIEGO RIVERS

INVESTIGATION

1949

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C. H. PURCELL
DIRECTOR

STATE OF CALIFORNIA

Department of Public Works

SACRAMENTO

June 17, 1949

The Council of the City of San Diego
Civic Center
San Diego 1, California

Subject: San Dieguito and San Diego Rivers
Investigation   File No. 451.2

Gentlemen:

Under general authority granted the Department
of Public Works by Article 2, Chapter 1 of the Water Code,
a cooperative agreement between the City of San Diego and
the Department of Public Works was executed on February 20,
1945, providing that the Department make an investigation
of water resources of the San Dieguito River and make
recommendations for their further development and utiliza-
tion. A superseding agreement, executed on May 11, 1945,
broadened scope of the work to include the San Diego River.
A supplemental agreement, dated May 1, 1947, provided ad-
ditional funds for the investigation and report.

Under terms of the three agreements, equal con-
tributions by the two parties provided a total amount of
$65,000 for the investigation and for preparation of and
publishing the report. Of this amount, $12,146.98 has been
expended under contracts with Fairchild Aerial Surveys, Inc.,
for aerial surveys and topographic maps of dam and reservoir
sites. Copies of these maps have been furnished the City of
San Diego.

Under direction of the State Engineer, the Divi-
sion of Water Resources of this Department has completed
the investigation, studies and report called for under the
foregoing agreements. The report so authorized, Bulletin
No. 55, "San Dieguito and San Diego Rivers Investigation",
1949, is transmitted herewith.

Yours very truly,

C. H. PURCELL

Director of Public Works

ACKNOWLEDGMENT

CONSULTANTS

At the request of the State Division of Water Resources, and under terms of
the regular cooperative agreement between the Federal government and the State of Cali-
fornia, the Soil Conservation Service of the United States Department of Agriculture made
an investigation and prepared a preliminary progress report on consumptive use of water
in San Pasqual Valley in San Dieguito Basin. The investigation was made and report pre-
pared by Harry F. Blaney, Senior Irrigation Engineer, and Dean C. Muckel, Associate Ir-
rigation Engineer, of the Division of Irrigation, under direction of W. W. McLaughlin,
Chief of Division. The report is reproduced in Appendix D, herein.

An examination of proposed Pamo dam sites and Sutherland dam site on Santa
Ysabel Creek was made by Chester Marliave, Consulting Geologist. Mr. Marliave also pre-
pared a preliminary estimate on stripping at one of the Pamo sites.

B. A. Etcheverry, Consulting Civil Engineer, and G. F. Mellin, Assistant Chief
Engineer, State Reclamation Board, conducted a field survey and estimated costs of acqui-
sition, at present-day market values, of land and improvements required in connection
with proposed reservoirs at Lake Hodges on San Dieguito River, and Mission Gorge on San
Diego River. Their reports on the Hodges and Mission Gorge sites are reproduced in Ap-
pendix C, herein.

ORGANIZATION

STATE DEPARTMENT OF PUBLIC WORKS
DIVISION OF WATER RESOURCES

C. H. Purcell . . . . Director of Public Works
Edward Hyatt . . . . State Engineer
A. D. Edmonston . . . . Assistant State Engineer

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The investigation was conducted and report prepared under the direction
of
P. H. Van Etten . . . . Principal Hydraulic Engineer

Principal Assistants

W. L. Berry . . . . Senior Hydraulic Engineer
G. L. Long . . . . Senior Hydraulic Engineer
H. M. Crooker . . . . . Associate Hydraulic Engineer
D. B. Willets . . . . . Associate Hydraulic Engineer

Assistants

W. A. Brown . . . . Senior Engineer, Dams
W. A. Perkins . . . . Senior Engineer, Dams
E. C. Marliave . . . . Senior Engineering Geologist
R. M. Edmonston . . . . Assistant Hydraulic Engineer
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C. W. Plumb, Jr. . . . Assistant Hydraulic Engineer
C. J. Cortright . . . . . . Assistant Civil Engineer
R. L. Cox . . . . Assistant Civil Engineer
J. L. James . . . . Senior Delineator
R. N. Jansen . . . . Delineator
C. T. Jeffryes . . . . Delineator
L. N. Case . . . . Senior Stenographer-Clerk

T. R. Merryweather . . . . . Administrative Assistant
Harry Searancke . . . Acting Administrative Assistant

CHAPTER I

INTRODUCTION

Water Problems of the San Diego Region

Because of its mild and equable climate, and scenic, recreational and cultural advantages, the San Diego region since the turn of the century has experienced consistent rapid growth in population. However, the tremendously accelerated increase resultant from expansion of its aircraft industry during World War II, and of naval and military establishments throughout the area, was unanticipated. Local public agencies had planned the orderly development of water sources and supplies to meet expected demands for several years in the future, but this program was inadequate for unprecedented requirements connected with war activities. In 1944, despite a fortunate series of wet years up to that time, the situation had become sufficiently critical to warrant immediate emergency action. Developed water sources were so overdrawn that the occurrence of dry years, to which the region is particularly susceptible, would soon exhaust inadequate reserves on hand. Surveys and negotiations were under way toward obtaining supplemental water from the Colorado River, a project that has since been consummated in construction of the San Diego Aqueduct, which now delivers water from the Metropolitan Water District's Colorado River Aqueduct to member agencies of the San Diego County Water Authority. However, it was desirable that investigation be made toward further development of local sources of water supply. It was known that both the San Dieguito and San Diego rivers had surplus waters, and that their safe yields could be increased by further development.

The termination of World War II did not eliminate critical water problems of the San Diego region. The wartime addition to population has to a large extent established itself permanently, and is presently being augmented by newcomers at a rate limited principally by living accommodations. Furthermore, the seasons since 1944 have been deficient in precipitation and runoff. Relief is afforded in the Colorado River supply available since December 1947, but studies indicate that eventually this source should be supplemented to assure a safe water supply for population and development that the San Diego area may now reasonably expect. It is apparent, too, that in order to meet probable ultimate demands for water, the further development of local sources offers appreciable physical and economic advantages, as compared with sole dependence upon imported water in this respect.

Authorization

The investigation and this report were initiated by a letter from the City of San Diego to the State Director of Public Works on September 13, 1944, wherein it was proposed that the State Engineer conduct a hydrographic survey of San Dieguito River, the project to be financed in amount of $20,000 by equal cash contributions of $10,000 from City and State, under cooperative agreement. General authority to conduct such cooperative investigations is included among powers granted the Department of Public Works by Article 2, Chapter 1 of the Water Code. Preliminary investigation having established the fact that cooperative study of the San Dieguito watershed, as requested by the City, was in the State's interest, the State Director of Finance on October 4, 1944, issued a

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promise of allotment of $10,000 from the Emergency Fund (Item 221, Chapter 62, Statutes
of 1943) for this purpose, contingent on its being matched by equal funds from sources
other than the State. An agreement between the City of San Diego and the Department of
Public Works was executed by the two parties on February 1 and February 20, 1945, respec-
tively. It provided that the Department make necessary surveys, explorations and cost
estimates connected with dams and reservoirs in the San Dieguito watershed, and trans-
mission lines therefrom; make estimates of present and future water utilization in the
watershed; make estimates of total and additional water yield under various combinations
of reservoirs in the San Dieguito watershed, with existing and possible future reser-
voirs of the City, and with present and possible future development on the San Dieguito
watershed; perform other field and office work agreed to by the parties; and prepare a
report by January 1, 1946, containing recommendations and general plans and cost esti-
mates for development of water resources of the San Dieguito watershed. It was agreed
that the City of San Diego would make estimates of cost of securing necessary water
rights. The City agreed to provide $10,000, and the State $10,000 from the Emergency
Fund, the moneys to be deposited in the Water Resources Fund and expended by the Depart-
ment of Public Works acting by and through the State Engineer.

On January 9, 1945, prior to execution of the foregoing agreement, the Council
of the City of San Diego, by Resolution No. 80445, requested that the State Director of
Finance incorporate in his budget the sum of $40,000 for the State Engineer to make
studies toward further development of waters of San Diego River and Cottonwood Creek.
The resolution was too late for budget action, but the request resulted in a superseding
agreement between the City and Department. executed by them on May 1 and May 11, 1945,
respectively. It provided that scope of surveys, studies and report, called for in the
original agreement, be increased to include San Diego as well as San Dieguito River, and
increased contributions of funds to $20,000 by each party, a total of $40,000 for the in-
vestigation. The additional State funds were provided from the Emergency Fund (Item 221,
Chapter 62, Statutes of 1943), as in the case of the first agreement.

Early in 1947 it became apparent that funds available were insufficient for
completion of an investigation and report of scale and scope contemplated under the above
agreements. A supplemental agreement was therefore executed by the City on April 24,
and the Department on May 1, 1947, providing for additional funds from each party in
amount of $12,500, or a total of $65,000 for the investigation. Source of the State
allocation was the Emergency Fund (Item 275, Section 2, Budget Act of 1945).

Copies of the three foregoing agreements are contained in Appendix A, "Agree-
ments Authorizing the Investigation and Report".

Prior Investigations and Reports
1. "Irrigation in California, Part II, Southern California", William Ham.
Hall, 1888. This report by the first State Engineer of California covers an investiga-
tion of water resources and irrigation development in Los Angeles, San Bernardino and
San Diego counties, which area then included the present Riverside and Imperial counties.
It specifically discusses San Dieguito and San Diego rivers and their existing and pro-
posed development.
2. Bulletin No. 100, "Irrigation Investigation in California", U. S. Depart-
ment of Agriculture, Office of Experiment Stations, 1901. Certain changes in water laws

of the State are recommended in this report, the result of an investigation of irriga-
tion conditions in 1900.

3. "Report of the Conservation Commission of the State of California", 1912.
This report covers investigations during 1912 by a special board created to study natural
resources of the State and recommend legislation for their conservation.

4. Bulletin No. 254, "Irrigation Resources of California and Their Utiliza-
tion", U. S. Department of Agriculture, Office of Experiment Stations, 1913. Results of
a comprehensive, state-wide study of irrigation development, made in 1912. are outlined
in this bulletin.

5. Water-Supply Paper 446, "Geology and Ground Waters of the Western Part of
San Diego County, California", U. S. Geological Survey, 1919. This report, prepared in
cooperation with the State Department of Engineering, constitutes a comprehensive geo-
logical study of the San Diego region.

6. Bulletin No. 4, "Water Resources of California", Division of Engineering
and Irrigation, State Department of Public Works, 1923. This report to the 1923 Legis-
lature, with its appendices, Bulletins No. 5, "Flow in California Streams", and No. 6,
"Irrigation Requirements of California Lands", is the first of several resulting from
studies known as the "California Water Resources Investigations". These studies were
initiated by legislative enactment in 1921, further investigations being authorized in
1925 and 1929, and were carried out under direction of the State Engineer. The 1923 re-
port contains an inventory of waters of the State, an estimate of gross agricultural area
and irrigation water requirements, and a preliminary plan for comprehensive development
of water resources of the State.

7. Bulletin No. 25, "Report to Legislature of 1931 on State Water Plan", Divi-
sion of Water Resources, State Department of Public Works, 1930. Under the authorization
mentioned in the preceding paragraph, this report summarizes water resources and require-
ments throughout California, and presents the "State Water Plan" for coordinated conser-
vation, development and utilization of water resources of the State. It contains
estimates of runoff from mountain and foothill drainage areas of San Diego County.

8. Bulletin No. 43, "Value and Cost of Water for Irrigation in Coastal Plain
of Southern California", Division of Water Resources, State Department of Public Works,
1933. Value and cost of water for irrigation of citrus fruits and avocados in San Diego
County areas are discussed in this report, prepared under cooperative agreement with the
College of Agriculture, University of California.

9. "Storm Types and Resultant Precipitation in the San Diego, California, Area",
Dean Blake, Monthly Weather Review, Volume 61, August 1933. This paper presents descrip-
tions of the four storm types experienced in the San Diego area, including their frequency
and characteristics.

10. Bulletin No. 48, "San Diego County Investigation", Division of Water Re-
sources, State Department of Public Works, 1935. Under authorization contained in Chapter
278, Statutes of 1933, an investigation of water resources, flood control and water re-
quirements of San Diego County was conducted during 1933 and 1934 by the Division of Water
Resources, in cooperation with the City and County of San Diego. Studies made were gener-
al in nature, except those pertaining to San Diego and Tia Juana rivers. As regards the
former, detailed recommendations were presented for a complete plan of conservation and
flood control development. For Tia Juana River detailed analyses and recommendations were
limited to flood control.

11. Bulletin No. 48-A, "San Luis Rey River Investigation", Division of Water
Resources, State Department of Public Works, 1936. This report is the result of a coop-
erative investigation by the United States Works Progress Administration, Division of

Water Resources, County of San Diego, City of Oceanside and Carlsbad Mutual Water Company. It supplements the general data of Bulletin No. 48 pertaining to San Luis Rey River with revised estimates of runoff and detailed studies of proposed dams and reservoirs.

12. <u>Technical Bulletin No. 524, "Silting of Reservoirs", U. S. Department of Agriculture, July 1936, Revised August 1939</u>. Data on rates and characteristics of silt deposition in Lake Hodges and Morena Reservoir in San Diego County are included in this bulletin.

13. <u>"Report on Program of Water Development, the City of San Diego and the San Diego Metropolitan Area", Louis C. Hill, Lester S. Ready and J. P. Buwalda, 1937</u>. The foregoing authors comprised a board of consulting engineers employed by the City of San Diego to determine future demands of the City and the adjacent metropolitan area, yield from local water sources and supplementary requirements, and to prepare preliminary plans and estimates for further water supply development. Their report contains data resultant from their investigation and studies. Development of local water sources, and plans for importation of Colorado River water are discussed.

14. <u>"Report on Municipal Water Systems - Report No. 3, San Diego Region", Committee on Transportation, Housing, Works and Facilities, State Council of Defense, April 1943</u>. This report, prepared in collaboration with the Division of Water Resources, was made in recognition of the importance of San Diego's contribution to the war effort, and of probable crippling effects of any interruption in its already critical water supply. The report analyzes municipal water supply systems of San Diego County as to adequacy, sources of additional supply, vulnerability, potential hazards in their physical works as affecting public or military establishments, and methods of protecting vulnerable features. It recommends essential additions to the physical works, and wartime protective measures. Alternate plans for importation of Colorado River water, either by pump lift from the All American Canal in Imperial Valley, or by gravity from the Metropolitan Water District's Colorado River Aqueduct, with diversion in the San Jacinto Valley, are discussed, and recommendation is made for immediate steps toward such importation by the most feasible route.

15. <u>"Utilization of the Waters of Lower San Luis Rey Valley, San Diego County, California", Division of Irrigation, Soil Conservation Service, U. S. Department of Agriculture, April 1945</u>. Under cooperative agreement with the State Division of Water Resources, the Soil Conservation Service conducted an intensive investigation and study of irrigated areas, consumptive use of water, ground-water fluctuations, precipitation and evaporation in San Luis Rey River Valley. This report presents resultant data and contains an estimate of the amount of water salvagable from consumptive use by native vegetation.

16. <u>"First Annual Report", San Diego County Water Authority, 1946</u>. History, organization and development of the Metropolitan Water District of Southern California and the San Diego County Water Authority are presented in this report, as well as factual data regarding the Colorado River water supply and the San Diego Aqueduct.

17. <u>"Estimated Range for Population Growth in California to 1960", State Reconstruction and Reemployment Commission, November 1946</u>. Included in this report are forecasts of population growth in San Diego County to the year 1960.

18. <u>"The Water Supply of the Escondido Soil Conservation District, San Diego County, California", Soil Conservation Service, U. S. Department of Agriculture, February 1947</u>. This report contains an estimate of safe yield of ground-water basins underlying the Escondido Soil Conservation District, including a small portion of the San Dieguito watershed. Hydrologic data and analyses pertaining to the Escondido region are included.

19. "Report on Water Supply of La Mesa, Lemon Grove and Spring Valley Irrigation District in San Diego County", Division of Water Resources, State Department of Public Works, April 1947. This is a brief study of water supply and requirements of the District, with particular reference to effects of delivery of Colorado River water through the San Diego Aqueduct, to supplement the District's local supply from San Diego River.

20. "Research Project No. 6, Part I, Population Trends in San Diego, 1900 Through 1960", Department of Research, San Diego City Schools, April 16, 1948. This paper is a compilation and discussion of forecasts of population of the City of San Diego to the year 1960, the forecasts being those by six independent interested agencies.

Scope

Under terms of the cooperative agreements authorizing the present investigation, its purpose has been to determine the best program of development of a water supply for the City of San Diego on the San Dieguito and San Diego rivers. The foregoing agreements did not authorize study of related water supply problems of other public agencies in San Diego County.

During 1933 and 1934 the Division of Water Resources made a comprehensive hydrologic investigation of San Diego County, results of which were published in 1935.* Precipitation was inventoried, and full natural flow of Pacific slope streams, as well as their safe yield under complete development, was estimated. A compilation was made of utilization of water, and existing development of surface and underground sources was described. Estimates of future water requirements were made. As regards flood flows, their characteristics, size and frequency were evaluated, and methods of flood control discussed. Primary purpose of the report was to present plans for water conservation and flood control on San Diego River, and for flood control on Tia Juana River. For San Diego River a detailed and thorough study was made, and a specific plan for construction and operation of dams, reservoirs and flood control works was recommended. A similar study of Tia Juana River resulted in the conclusion that flood control was not economically justified at that time. For remaining San Diego County streams, the studies were general in nature, without recommendations of definite plans for either conservation or flood control.

It is apparent that duplication of material presented in Bulletin No. 48 is unnecessary and unjustified. In planning work to be accomplished under the present investigation, its scope was therefore limited to supplemental surveys and studies, which when used in conjunction with those of Bulletin No. 48 would be sufficient for complete analysis of problems of water conservation and flood control of the two watersheds. In the case of San Dieguito River these included intensive study of hydrology, culture and water requirements within the basin, together with detailed engineering and economic analysis of conservation and flood control works under a recommended plan of development. In the case of San Diego River, with such a plan already presented in Bulletin No. 48, new work under this investigation included only required re-examination of certain phases of the earlier studies to bring them up to date, and consideration of dams and reservoirs not included in the earlier investigation.

*Bulletin No. 48, "San Diego County Investigation", Division of Water Resources, State Department of Public Works, 1935.

Field work for the present investigation included such surveys of proposed dam and reservoir sites by aerial photography, geologic examination of dam sites, and valuation surveys for purchase of necessary lands, as were required. A crop survey was made of lands in San Pasqual Valley in San Dieguito Basin. In the same valley a meteorological station, five stream gaging stations, and a number of test wells to determine ground-water fluctuations, were installed, and a program of systematic observations inaugurated. Data from these continuing observations are incomplete at this time, and therefore are not reported herein. Available data on precipitation, stream flow, utilization of water, water rights and other pertinent subjects were collected from private and public agencies.

The five San Pasqual Valley stream gaging stations, situated so as to measure surface inflow and outflow from the valley, were designed by the Division of Water Resources and installed largely by the City of San Diego under the Division's supervision. Equipment, including still wells, gages, houses and recorders, was furnished by the United States Geological Survey, which agency has assumed operation and maintenance of the stations and will publish the records, under terms of its general cooperative agreement with the State of California. The two key gaging stations on the main stream, at the upper and lower ends of the valley, respectively, are wading sections with natural control, equipped as are the other stations with staff gages, still wells and housed automatic water stage recorders. A high water station on Guejito Creek is located at the State highway bridge, while an upper station, consisting of a reinforced-concrete Parshall flume, measures low flows. Santa Maria Creek is measured by wading, at the restored site of previous stream gaging operations, the natural control having been raised and improved.

The San Pasqual Valley Meteorological Station is located on county property, and was designed and constructed by the Division, with assistance by the City. Equipment was largely furnished by the Soil Conservation Service of the United States Department of Agriculture, and is operated and maintained by the Division. The equipment is protected by a steel fenced enclosure, and consists of an 8-inch standard rain gage, 4-foot standard evaporation pan, maximum and minimum thermometers, hygro-thermograph and an anemometer. Thermometers and hygro-thermograph are housed in a standard shelter.

It was necessary, preliminary to engineering and economic analysis of proposed dams, reservoirs and appurtenant works, to prepare topographic maps of suitable scales from aerial survey data. Office studies also included compilation of hydrologic data, such as precipitation, flow of streams, ground-water fluctuations and storage, consumptive use and requirement of water under present and future conditions, and flood flows. Yield and cost of water, both firm and secondary, were studied for various combinations of existing and proposed reservoirs, under several possible systems of operation. Consideration was given to reservoir and channel control of floods.

Chapters IV to VIII, inclusive, of this report are concerned exclusively with data and studies pertaining to San Dieguito Basin. Chapter IX contains the result of current studies of San Diego River.

CHAPTER II

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

In this chapter there is presented a summary of data developed in greater detail in subsequent chapters of this report, as well as conclusions and recommendations derived therefrom.

Water Requirements of City of San Diego

After many decades of sustained rapid growth prior to 1940, the City of San Diego experienced five years of greatly accelerated expansion, coincident with and occasioned by World War II. This increase was accompanied by water demands in excess of developed safe yield, so that reserves in storage were seriously depleted. Drought years which followed the wet season of 1943 produced little runoff, and although water demands decreased some ten per cent from their 1945 peak average of about 50 million gallons per day, reserves continued to decline. At the end of 1948, reservoir storage space available to the City was filled to less than 25 per cent of its 398,000 acre-foot capacity, and safe yield from this source, defined for purposes of this report as sustained supply during the record drought from 1895-96 to 1904-05, inclusive, was an estimated 30 per cent of normal expectancy, or about 9.6 million gallons per day. However, in December 1947 the City had received its first deliveries of Colorado River water through the newly completed San Diego Aqueduct. This conduit connects with the Colorado River Aqueduct of the Metropolitan Water District of Southern California at the west portal of its San Jacinto tunnel, and extends to San Vicente Reservoir of the city system.

The San Diego County Water Authority was organized to receive and distribute Colorado River water to its member agencies, of which the City of San Diego is by far the largest. The City's entitlement, based upon 1946 assessed valuations, amounts to about 85 per cent of capacity of the San Diego Aqueduct. The City can depend upon firm delivery of approximately 48.9 million gallons per day from this source, an amount in itself greater than present demands. Total safe supply to the City, under present conditions of depleted storage and including the Colorado River water, is estimated to average 58.5 million gallons per day. San Diego is thereby relieved from immediate concern with reference to the sufficiency of its water supply. If a fortuituous series of wet years occurs, the City may attain the full measure of developed yield from local sources, and a total safe supply of 80.8 million gallons per day. It cannot be stated how soon this may occur. However, it was estimated in Bulletin No. 48* that, after construction of reservoirs on San Diego River for complete conservation development, eight years would elapse, on the average, before attainment of full safe yield. In the present stage of partial development, and with nearly 25 per cent of storage filled, a somewhat shorter average period might be expected.

Ultimate water requirements of the City of San Diego are estimated from a consideration of duty of water over the gross city area under assumed ultimate cultural conditions. In 1943 the Division of Water Resources estimated average ultimate seasonal duty

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* Bulletin No. 48, "San Diego County Investigation", Division of Water Resources, State
  Department of Public Works, 1935.

over the Raymond Basin area, consisting of the City of Pasadena and vicinity, at 1.29 acre-feet per acre. The estimate was the result of intensive surveys and studies by the City of Pasadena and the Division, and is considered reasonably authoritative. Hydrologic factors indicate that an equivalent seasonal duty for the San Diego city area is approximately 1.4 acre-feet per acre. Cultural differences between the two communities under ultimate development should be compensating, except as regards military and naval establishments. These features are exclusive to San Diego, and their water requirements are largely independent of ordinary area-duty relationships. Accordingly, an allowance of 15.0 million gallons per day is made for ultimate armed force needs, roughly equivalent to peak World War II demands. Application of the foregoing seasonal duty of 1.4 acre-feet per acre to the approximately 61,100 acres within the present city boundaries results in an estimate of 85,500 acre-feet seasonally, or 76.3 million gallons per day, for ultimate civil requirements. A further working allowance of ten per cent is provided as a factor of safety, resulting in an estimate of 100 million gallons per day as total water requirements for the City of San Diego, under conditions of ultimate development of its present incorporated area.

Population of the City of San Diego increased from 203,000 to 363,000 during the period from 1940 to early in 1946, a rise of about 80 per cent, and was probably even higher at the war's end in the fall of 1945. Water consumption increased at an even greater rate, from 23.6 to 50.2 million gallons per day from 1940 to 1945, a rise of more than 110 per cent. This indicated an increase in per capita consumption from 116 to 128 gallons per day. After study of population forecasts by several competent authorities, it is believed that the City of San Diego may reasonably expect a population of about 500,000 by 1960. Assuming average per capita daily consumption of 125 gallons, water requirements of the City in 1960 will be an estimated 62.5 million gallons per day, four million gallons per day more than the estimated safe yield of 58.5 million gallons daily now available, but some 18 million gallons per day less than the estimated maximum safe yield of 80.8 million gallons daily from the existing development, once the city reservoirs are filled. That they will fill prior to 1960, or at least be augmented sufficiently that safe yield will meet 1960 requirements, is considered probable.

In view of the foregoing, it might be assumed that the City need not pursue further development of its water supply until 1960 or later. Such an assumption, however, is not conservative. Further, it does not take into account certain practical considerations regarding San Diego's water supply. Planning for a municipal supply should be on a sound and conservative basis. Forecasts of population growth upon which estimates of future requirements are based are inherently subject to wide error, and demand for water may be greater than now anticipated. Also, it is considered probable that in their quest for water certain communities adjacent to the City will eventually be annexed to it, thus increasing its overall requirements. Furthermore, accretion of additional storage in local reservoirs is dependent upon vagaries of the weather, and may or may not be attained by 1960. It is also dependent upon rigid adherence to a schedule of reservoir operation for safe yield, which may or may not be followed. Finally, the City of San Diego has a large investment in real property and water rights required for further water supply development in San Dieguito Basin. The investment is secured and validated by a 1947 filing on flood waters of San Dieguito River. To protect its property and water rights and maintain the filing the City must show reasonable diligence in putting the waters to beneficial use.

Several sources of additional supply are available to the City, including both San Dieguito and San Diego river basins. The remaining streams of the western slope in

San Diego County present some possibilities for further development. Another source of supplementary water for the City lies in importation of additional Colorado River water, through construction of the proposed second barrel of the San Diego Aqueduct, which construction will approximately double the aqueduct capacity.

San Dieguito Basin

Because of its relatively large undeveloped water resources and favorable geographic position, San Dieguito River and its tributary system merit consideration in connection with any program for supplementing the water supply of the City of San Diego.

Description

San Dieguito River, known above its confluence with Santa Maria Creek as Santa Ysabel Creek, drains a basin roughly triangular in shape, lying slightly to the north of the center of San Diego County. The basin's longer axis of about 41 miles bears from northeast to southwest, and the watershed area of 347 square miles has a maximum width of about 15 miles. The river, rising on the slopes of Volcan Mountain at an elevation exceeding 5,500 feet, flows through a series of canyons and narrow valleys for some 53 miles, and enters the Pacific Ocean a mile north of Del Mar and about 19 miles north of downtown San Diego. The basin lies between the major watersheds of San Luis Rey River on the north and San Diego River on the south. Principal tributaries are Witch Creek, Black Canyon, Temescal Creek, Roden Canyon, Guejito Creek and Santa Maria Creek, all but the first and last named of which enter from the north.

Three principal dam and reservoir sites occur along the main stream. The uppermost of these is marked by the partially constructed Sutherland Dam, located about seven miles northeast of Ramona, at streambed elevation of about 1,900 feet. Drainage area at this site is 54 square miles and averages 3,350 feet in elevation. The sites which have been considered for Pamo Dam are situated a little more than a mile below the mouth of Temescal Creek, where streambed elevation is approximately 850 feet, and the drainage area of 111 square miles averages 2,900 feet above sea level. Hodges Dam is located about 12 miles upstream from the ocean at streambed elevation of 200 feet. Its 303 square miles of drainage area average 1,900 feet in elevation. Lake Hodges, impounded by a concrete multiple-arch dam 115 feet in height, is a conservation reservoir with present capacity of approximately 33,600 acre-feet.

Principal ground-water sources occur in alluvial deposits underlying San Dieguito and San Pasqual valleys. Ground water is also obtained from decomposed crystalline rocks beneath Santa Maria and Guejito valleys. Fractured or decomposed rocks with some water-storing capacity constitute much of the surface of the highland areas, and intermittent shallow alluvium occurs along stream channels, but these sources are not exploited to any appreciable extent.

San Dieguito Basin has subtropical climatic characteristics, temperate and equable near the coast, but with wider range in extremes in the interior and at higher elevations. Precipitation varies from an average of approximately ten inches in seasonal depth along the coast to as much as 40 inches at the crest of the mountains. Adjoining the basin, the eastern slope of the mountains is characterized by a desert climate of extremely low precipitation and wide range in temperature.

Natural vegetation throughout the basin is generally sparse. However, dense stands of brush and trees occur along water courses, and northern slopes of hills and mountains are chaparral covered to varying degrees. Conifers occur in the mountains at elevations over 4,000 feet.

San Dieguito Basin is lightly populated and contains no incorporated municipalities, except for the small portion of the City of Escondido lying within the basin boundary north of Lake Hodges. The town of Ramona in Santa Maria Valley, with population of about 1,400, is the largest urban development in the basin. Highland areas contain only a few small settlements and isolated ranches. San Pasqual and San Dieguito valleys are given over to farms and ranches, while the ridge of hills north of Lake Hodges contains numerous citrus groves. A resort subdivision, Del Dios, is situated at the western extremity of Lake Hodges and has an estimated population of 600. North of the river and some four miles from the coast, the community center of Rancho Santa Fe is surrounded by estate type homes and small ranches. Total population of the basin is estimated at about 5,400.

Agriculture is the predominant activity in San Dieguito Basin, and the only industry of importance at the present time. The San Diego County Fair and horse racing are seasonal activities in San Dieguito Valley, and scenic and mountainous portions of the area attract a moderate number of campers and tourists. From United States census data it is estimated that approximately 5,000 acres were irrigated within the watershed in 1939, with about 680 irrigated farms and $1,000,000 invested in irrigation enterprises. Crop surveys conducted by the Division of Water Resources in 1948 show that approximately 7,300 acres are presently irrigated within the watershed, of which about 3,000 acres are served by water imported from the San Luis Rey River. Principal irrigated crops are citrus, alfalfa and field crops. There is also a considerable amount of stock raising, dairying and dry farming of grain, hay, grapes and deciduous fruits.

The area is adequately served by highway and rail transportation facilities. U. S. Highway 101 and the Atchison, Topeka and Santa Fe Railway cross San Dieguito River at its mouth. Some 15 miles inland, U. S. Route 395 crosses the watershed from north to south. Several secondary state and local highways provide lateral connections and serve the remainder of the basin.

Water Supply
The water supply of San Dieguito Basin is largely derived from precipitation which falls within the watershed. There is, however, an increasing import of water by the Escondido Mutual Water Company, now averaging about 2,000 acre-feet per season, from the San Luis Rey River to the north. Little, if any, of this water reaches San Dieguito River as accretion to runoff. Although diversion facilities from the San Diego Aqueduct are available, and some Colorado River water has been stored in Lake Hodges, none of this water has as yet been utilized within San Dieguito Basin. Based upon entitlements derived from 1946 assessed valuations, it is estimated that the Santa Fe Irrigation District will ultimately import about 400 acre-feet of Colorado River water to San Dieguito Basin each season.

Precipitation
Precipitation in San Dieguito Basin occurs principally as rainfall, although minor snowfalls are common in the high mountains. On the average, more than 70 per cent

of seasonal rainfall occurs in the four months from December to March, inclusive, and summers are characteristically long and dry. Precipitation increases rather uniformly with rise in elevation and distance from the coast. There is wide variation in amount of rainfall from season to season, with extremes ranging from less than 50 to more than 200 per cent of the long-time average.

Because of its vital importance in this arid region, rainfall has been a subject of local interest since early days, and private and public agencies have maintained numerous precipitation records, the oldest of which is that at San Diego, dating from 1850. Thirty-one precipitation stations were chosen for this study as being representative of San Dieguito Basin, 14 of which were within the watershed and the remainder adjacent to or near it.

By examining the San Diego record it was determined that the 50-year period, 1891-92 to 1940-41, inclusive, was one of approximately normal precipitation, as well as one embracing the majority of rainfall records pertaining to San Dieguito Basin. Accordingly, it was chosen as a base period for this study, and short-term records were extended by standard methods to cover it. A map showing lines of equal precipitation was then drawn, and by planimetering the area between these isohyets in each drainage area, mean seasonal precipitation was determined for the 50-year period. For the 303 square miles of drainage area above Hodges Dam, seasonal precipitation for the base period averaged 20.89 inches. Similarly, for the 111 square miles above Pamo dam site precipitation averaged 26.26 inches seasonally, while for the 54 square miles above Sutherland Dam it was 28.06 inches. Average seasonal precipitation for the entire 347 square miles of San Dieguito watershed was 19.63 inches. The season utilized in this report in connection with precipitation is the so-called "precipitation season", from July to June, inclusive.

Runoff

Stream flow in San Dieguito Basin is flashy, ranging from negligible discharge in most summer seasons to occasional torrential floods of destructively high peak flow but relatively short duration, occurring during protracted winter storms. Such floods produce the greater part of total runoff, and are experienced only at intervals of five to six years, on the average. Study of runoff characteristics discloses a rather well defined periodic or "cyclic" behavior. Within an apparent 25-year runoff period, shorter periods averaging about five years in length have occurred with marked regularity, the only notable non-conformity having been during the ten-year drought from 1896 to 1905, which was unbroken by an above normal season.

Runoff is subject to even wider seasonal variation than precipitation, and during the 50-year normal period 1891-92 to 1940-41, inclusive, had extremes of 1.1 and 762 per cent, respectively, of the long-time seasonal mean. In only 12 seasons was average runoff exceeded, yet these accounted for approximately 74 par cent of total runoff during the 50 years. On the other hand, for seven consecutive seasons during the 1896-1905 drought, average runoff was only about 11 per cent of the 50-year average. Within the season all but a minor portion of runoff occurs during winter and spring, its distribution generally following that of precipitation. Peak runoff month is usually February or March and rarely occurs after March. Stream flow falls off rapidly after final spring rains, and while there is small perennial flow in the mountains, and in valleys where shallow alluvium causes rising water, this contribution to seasonal runoff is small.

Recorded stream flow measurements in the basin date from 1906, but it was not until 1912 that a comprehensive stream gaging program was inaugurated by the cooperative endeavors of the Volcan Land and Water Company and the United States Geological Survey. Of particular interest to the present investigation are stream flow records at the three principal dam sites, Sutherland, Pamo and Hodges. The record for Sutherland dam site is continuous from 1912 to date. For Pamo dam site the record also starts in 1912 but is broken by a 20-year period with no record, from February 1923 to October 1943, for which period runoff was estimated from its relation with that at Sutherland. Stream flow measurements have been continuous at the site of Hodges Dam since 1916. Records presented in this report differ from those of Bulletin No. 48 in that they refer to actual runoff at the stations, rather than full natural runoff. Full natural runoff is that which would occur under natural conditions, unimpaired by upstream diversion, use and storage development and without import of water into the basin. In many hydrologic studies, full natural flow is evaluated in order to facilitate comparison between runoff of different streams, or different points on the same stream. In the present investigation, however, it was desired to determine additional yield obtainable by construction of conservation works on San Dieguito River. An evaluation of actual runoff at the several sites was essential for this purpose.

In order to evaluate long-time mean runoff, estimates were made of runoff at each of the three dam sites, extending back through the seasons of 1887-88. In general, these estimates for years prior to the beginning of record were made by comparison with nearby streams, utilizing relationships established during periods of mutual record.

Although the relationship between rainfall and runoff in San Dieguito Basin is erratic seasonally, over a period of many years the two should conform closely. For this reason, the 50-year normal precipitation period 1891-92 to 1940-41, inclusive, was assumed also to be one of normal runoff. Mean seasonal runoff at Sutherland, Pamo and Hodges dam sites during the 50-year period is estimated to have been 15,600 acre-feet, 25,000 acre-feet and 40,700 acre-feet, respectively. These average seasonal amounts are essentially the same as would have occurred under present conditions of culture and development. The season referred to in connection with runoff is the so-called "irrigation season", from October to September, inclusive. This season is generally utilized throughout this report, except in connection with precipitation.

Water Utilization

Waters of San Dieguito Basin are utilized for irrigation and domestic purposes within the watershed boundaries, and by export for irrigation, domestic and municipal purposes in coastal areas both to the north and south of San Dieguito River. Most of the use is by those organized water service agencies which obtain their supply from Lake Hodges and then export the larger portion of it. Total average seasonal use under present conditions is estimated at 13,550 acre-feet. Under expected conditions of ultimate development it is estimated that about 34,000 acre-feet will be utilized.

Under present conditions, only about four per cent of all precipitation falling on the San Dieguito watershed is developed for higher forms of use, such as domestic, municipal or irrigation. The remaining 96 per cent, an average of approximately 350,000 acre-feet seasonally, is lost to economic utilization, excepting for that undetermined portion consumed in production of natural grasses utilized for grazing. Even under proposed complete conservation development of the basin, only a little more than nine per cent of

precipitation will actually be put to the higher forms of beneficial use. Principal water lost is by consumptive use of native vegetation, estimated to average about 320,000 acre-feet seasonally, which has been considered as including evaporation from soil and natural water surfaces. This loss is subject to only minor reduction by feasible conservation measures. A considerable amount of water, averaging an estimated 25,000 acre-feet per season, now flows into the Pacific Ocean from San Dieguito River. It is from salvage of this water that further conservation may be principally achieved. Evaporation losses from reservoir surfaces, at present averaging about 5,000 acre-feet seasonally, will increase with proposed additional conservation development.

Water Service Agencies

Principal water service agencies utilizing water from San Dieguito Basin consist of three irrigation districts, one private corporation and the City of San Diego. By virtue of contractual commitments by the City to supply the San Dieguito and Santa Fe irrigation districts and Del Mar Water, Light and Power Company with water, these agencies are commonly known as the "Committees".

San Dieguito Irrigation District serves domestic and irrigation water to a gross area of about 4,000 acres along the coast north of San Dieguito River, between Batiquitos and San Elijo lagoons. Its contract with the City of San Diego assures the District of a maximum seasonal supply of 3,200 acre-feet of water from Lake Hodges. As a result of its recently acquired membership in the San Diego County Water Authority, the District is entitled to an estimated 500 acre-feet per season of Colorado River water, based upon 1946 assessed valuations. No deliveries were received from this source up to the end of 1948. The District's entitlement will increase to an estimated 1,000 acre-feet per season when the second barrel of the Colorado River Aqueduct is constructed. During the 1946-47 season, 3,384 acre-feet of water were utilized by the San Dieguito Irrigation District, the excess over the Lake Hodges entitlement being purchased from Del Mar Water, Light and Power Company. It is believed that this demand is in excess of average under present conditions, and largely attributable to drought conditions. Present water utilization by the District is estimated to average about 2,810 acre-feet per season, the mean for the five seasons up to and including 1946-47. Under conditions of ultimate development of San Dieguito Irrigation District, it is estimated that water requirements will average about 4,800 acre-feet per season.

Santa Fe Irrigation District provides irrigation and domestic water to a gross area of about 10,000 acres, most of which lies on the ridge between San Elijo Creek and San Dieguito River. By virtue of its contract with the City of San Diego the District is assured a maximum seasonal supply of 4,300 acre-feet of water from Lake Hodges. Like the neighboring San Dieguito Irrigation District, the Santa Fe Irrigation District has recently acquired membership in the San Diego County Water Authority. On the basis of 1946 assessed valuations, the resultant entitlement to Colorado River water is estimated at about 400 acre-feet per season. No deliveries were received from this source up to the end of 1948. The District's entitlement will increase to an estimated 700 acre-feet per season when the second barrel of the Colorado River Aqueduct is constructed. It is estimated that present water utilization by Santa Fe Irrigation District averages about 3,280 acre-feet per season, the mean from 1942-43 to 1946-47, inclusive, and that under conditions of ultimate development 6,200 acre-feet per season will be required.

Ramona Irrigation District serves domestic water, and a small amount of irrigation water, to a gross area of 660 acres at the townsite of Ramona in Santa Maria Valley.

Its water supply is obtained from a battery of shallow pumping wells in sands of the channel of Santa Maria Creek, north of the town. Present seasonal water utilization is estimated to average about 240 acre-feet, and is limited by safe yield of the ground-water basin. Lack of financial capacity has so far prevented development of further water supply for the District. However, if the District can add to its local development, or secure additional water from other sources, its requirements under ultimate conditions may reach an estimated 700 acre-feet per season.

The Del Mar Water, Light and Power Company, a private corporation, supplies water for domestic and municipal uses in the unincorporated coastal community of Del Mar, immediately south of San Dieguito River. Its contract with the City of San Diego assures it of a maximum seasonal supply of 724 acre-feet of water from Lake Hodges. Present water utilization is estimated to average about 250 acre-feet per season, the mean for the period from 1942-43 to 1946-47, inclusive. Under conditions of ultimate development it is believed that about 1,100 acre-feet of water will be required for the gross service area of approximately 1,520 acres then served by the Company.

As early as 1920 the City of San Diego contracted to obtain water from Lake Hodges in an amount up to 3.0 million gallons per day, to be used in its La Jolla service area. In 1925 the City effected a lease-sale agreement with the San Dieguito Water Company, then owner of Lake Hodges and related water rights, reservoir sites and regulating and distribution works, known as the "San Dieguito System", under which the City leased the system for a 30-year period, with option to buy. The agreement provided that the City assume heretofore cited obligations of the San Dieguito Water Company to the several Committees. Ownership of the system was acquired by the City in 1939, through payment of the remainder due under the 1925 contract. Delivery of Lake Hodges water to La Jolla is limited by capacity of existing transmission lines, and averages about 3,070 acre-feet per season at this time. Future use of water from San Dieguito Basin by the City of San Diego will be determined by the amount of additional yield developed within the basin. Under the complete conservation development recommended in this report, it is estimated that the City will realize approximately 19,000 acre-feet of water from San Dieguito Basin seasonally, the remainder after ultimate requirements of foregoing water service agencies and other users of water from the basin have been satisfied.

Other Water Users

In addition to the organized water service agencies described in the preceding section, waters of San Dieguito Basin are utilized by several small mutual water companies or associations, three Indian reservations and a number of individuals. In the aggregate this use is small in comparison with that by the water service agencies, and no appreciable change in this respect is expected in the future.

Land irrigated by San Dieguito Basin water, other than that under water service agencies, is estimated at about 3,000 acres at the present time. Assuming an irrigation duty of 1.3 acre-feet per acre, current seasonal water utilization by such other water users averages approximately 3,900 acre-feet. Appreciable increase in use of San Dieguito Basin water by others than water service agencies is not anticipated, and such use should average about the same under conditions of ultimate development as at the present time, or approximately 3,900 acre-feet per season.

Export

Export of water from San Dieguito Basin is exclusively by diversion from Lake Hodges, and such exported water is utilized by the City of San Diego and the several San Dieguito Committees for irrigation, domestic and municipal purposes in areas along the coast both to the north and south of San Dieguito River. Portions of the water delivered to both Santa Fe Irrigation District and Del Mar Water, Light and Power Company are utilized within San Dieguito Basin and do not comprise export. At the present time, export is estimated to average about 7,500 acre-feet seasonally. It is estimated that under conditions of ultimate development, export from San Dieguito Basin will average about 26,000 acre-feet seasonally.

Existing Conservation Works

Hodges dam and reservoir and related diversion, regulation and transmission facilities, all of which are presently owned and operated by the City of San Diego, comprise the only important existing water supply development in San Dieguito Basin. Construction of Sutherland Dam on Santa Ysabel Creek, about 6½ miles northeast of Ramona, was started by the City in 1927, but this conservation project was abandoned before completion.

Hodges Dam, located on San Dieguito River about 12 miles upstream from the ocean, was completed in 1919. It is a concrete multiple-arch structure, with an overflow spillway. Capacity of the reservoir was 37,699 acre-feet when constructed, but has been reduced to approximately 33,600 acre-feet by silting. It is estimated that safe seasonal yield of the reservoir during the critical drought period from 1895-96 to 1904-05, inclusive, would have been 6,700 acre-feet.

Water is released from outlets in Hodges Dam into Hodges Conduit, consisting for the most part of open concrete-lined channel, which leads 4.65 miles to San Dieguito Reservoir. San Dieguito Dam is located on a minor tributary of Escondido Creek. It is likewise of concrete multiple-arch construction, with a siphon spillway. San Dieguito Reservoir, with storage capacity of about 1,100 acre-feet, is utilized only for regulatory purposes, and water is drawn from it for delivery to the City of San Diego, the San Dieguito and Santa Fe irrigation districts and the Del Mar Water, Light and Power Company.

Complete Conservation Development

The objective of any plan for complete conservation development in San Dieguito Basin should be to conserve as large a percentage as possible of runoff now wasting into the ocean, as well as to effect any practicable salvage of water now wasted through consumptive use by natural vegetation. The three principal sites for surface reservoirs, designated as Hodges, Pamo and Sutherland, have been heretofore described. The only consequential underground reservoirs are those underlying San Dieguito and San Pasqual valleys.

Yield from Surface Reservoirs

In the San Diego region water is so vital a commodity that relative yield of several proposed conservation works is of primary importance in comparing their respective merits. The term "safe yield", as used in this report, refers to the amount of water which could have been supplied seasonally from a given source, without deficiency, throughout the critical period of dry years from 1895-96 to 1904-05, inclusive. However, in drawing comparisons between proposed reservoirs in San Dieguito Basin it was desirable to utilize the best runoff information available. Reliable streamflow records are limited to the period subsequent to 1912, during which period an extended drought occurred during the 20 years

from 1916-17 to 1935-36, inclusive. This drought was preceded by two wet seasons, one of which was the extreme flood season of 1915-16. The occurrence of these wet seasons assures that proposed reservoirs would have been filled at the onset of the dry period, and imposes a definite objective on the yield studies, that is, the complete conservation of 1915-16 runoff. Yield studies, therefore, have been made to cover the period subsequent to 1914. Yield is fixed by the critical period 1916-17 to 1935-36, inclusive, and is hereinafter referred to as the "1917-36 firm yield".

The ten-year drought from 1895-96 to 1904-05, inclusive, was more severe than the critical period utilized for yield studies in this report. Studies based upon estimated runoff indicate that safe yield from proposed reservoirs during the 1896-1905 drought would have varied from 59 per cent of 1917-36 firm yield in the case of the existing Lake Hodges, to 95 per cent for an enlarged Lake Hodges of size to assure complete basin development.

As regards surface reservoirs, principal factors entering into determination of yield are runoff, evaporation and draft. Runoff in San Dieguito Basin has been discussed in a prior section of this summary. In estimating evaporation losses, use was made of records of evaporation at Hodges, Morena, Barrett, Henshaw and Cuyamaca reservoirs. Average gross seasonal depth of evaporation from Lake Hodges, based upon 25 years of record at that site, is 57.28 inches. For Pamo and Sutherland reservoirs, seasonal evaporation was estimated from observed variation of evaporation with elevation and distance from the coast, and its monthly distribution by comparison with records at existing reservoirs in the vicinity. Estimated average gross depth of seasonal evaporation at Pamo and Sutherland reservoirs is 64.0 and 67.0 inches, respectively.

Draft upon reservoirs is governed by demand, but may be affected by characteristics of transmission and distribution works. Estimates for this report take into consideration assumed present use by the San Dieguito Committees, with distribution in accordance with actual weighted average monthly use during recent years. The excess of yield above use by the Committees was assumed to be delivered to the City of San Diego at rates proportioned on the basis of its average monthly consumption during recent years.

Utilizing the foregoing data on runoff, evaporation and draft, studies were made to determine yield of reservoirs to the City of San Diego throughout the period from 1914-15 through 1944-45, under various assumptions as to capacities, combinations of reservoirs and methods of operation. Significant conclusions derived from the yield studies covering the period from 1914-15 to 1944-45, inclusive, are summarized below:

    a. The existing Lake Hodges had a 1917-36 firm seasonal yield of 11,400 acre-feet.

    b. Complete conservation of surface runoff above Hodges Dam would have required approximately 340,000 acre-feet of storage capacity. Resultant 1917-36 firm seasonal yield would have been about 30,000 acre-feet.

    c. Under various combinations of storage capacity, divided between Hodges, Pamo and Sutherland reservoirs but involving the same aggregate capacity, 1917-36 firm yield would have been approximately equal, provided Lake Hodges had sufficient capacity to prevent spill.

    d. Under the several plans for complete basin development studied, minimum storage capacity of Lake Hodges required to fully regulate runoff below Pamo would have been 174,400 acre-feet.

Conservation reservoirs should be available far enough in advance of anticipated water demands to permit, under normal expectancy, the catchment of runoff sufficient to develop required yield. Length of this period is related to size of the concerned reservoir as compared with average seasonal runoff. In the case of a large conservation reservoir at Lake Hodges, conservative analysis indicates that construction should precede demands by a period of about ten years. Even under adverse runoff conditions, sufficient yield should be attained in this time to meet initial requirements of the City of San Diego for supplementary water, with reasonable expectancy that increasing storage and yield would thenceforth keep pace with increasing demands.

Sutherland Reservoir

The City of San Diego commenced construction of a dam at the Sutherland site in 1927. After a considerable amount of foundation excavation had been accomplished, conditions were found to be unsatisfactory for the proposed concrete multiple-arch dam, and construction of a similar structure was started at a second location about 1,000 feet upstream. After seven buttresses in this structure had been partly constructed and a portion of the spillway excavation accomplished, the project was abandoned for reported financial and policy reasons. Assuming that the existing work has been done in accordance with the indicated contract plans and specifications, its completion is structurally feasible.

The dam upon which construction was halted was to have had a crest length of approximately 1,025 feet, and height to crest of spillway gates above streambed of 158 feet, at which elevation the reservoir storage capacity would have been 36,724 acre-feet. The spillway, consisting of an open cut in the right abutment, was to have been controlled by three drum gates. The site was core drilled by the City of San Diego in 1927, and more complete information relative to foundations resulted from actual construction operations. Foundation material consists of hard gneiss, with solid rock near the surface at streambed. For purposes of this report, a concrete pipe transmission line, 13.5 miles in length including one-half mile of tunnel, is proposed to divert water by gravity from Sutherland Reservoir into the San Vicente Creek drainage, where it can be picked up by existing facilities of the City of San Diego. Based upon April 1947 prices, capital cost for completing the existing dam and reservoir and constructing the conduit is estimated at about $3,677,000, with annual costs of $163,500.

Pamo Reservoir

Three possible dam sites have been considered in connection with Pamo Reservoir, but the one upon which planning studies of this report are based is the uppermost, at the head of a canyon reach of Santa Ysabel Creek, a little more than a mile downstream from Temescal Creek. The only available exploration data on foundation conditions pertain to a site 1,700 feet downstream from the one chose for planning studies. However, geological reconnaissance indicates that the chosen site is the more favorable for reservoirs of required capacities, and that dam structures there should be of earth-fill type. Detailed foundation explorations would be required before a final decision as to utilization of this dam site is made.

Studies were made for three sizes of rolled earth-fill dam, with reservoir storage capacities of 90,000, 135,000 and 163,400 acre-feet, respectively. Lengths of dam at crests are 1,800 feet, 2,060 feet and 2,230 feet for the respective sizes, with heights to spillway lips above streambed of 181 feet, 208 feet and 224 feet. A reservoir of the largest size would be required at Pamo to retain combined runoff of the 1914-15 and 1915-16

seasons, less draft and evaporation. Embankment sections have a 30-foot crown width, and three to one slopes both upstream and downstream. Because of adverse topographic and geologic conditions on the abutments, spillways present a difficult problem, and one expensive of solution.

In order to permit comparison between yield from Sutherland, Pamo and Hodges reservoirs, costs of delivering the water to approximately equivalent points on the existing system of the City of San Diego are added to reservoir storage costs in each instance. Plans for Pamo Reservoir route the water by gravity for 19.6 miles through a concrete pipe line to a point two miles south and one-half mile east of Hodges Dam, the proposed site of a filtration plant. From there it is conveyed by 16.7 miles of similar gravity conduit to Chesterton Tank near the south edge of Linda Vista Mesa, two miles north of San Diego River, where it is assumed that connection can be made to the existing city system.

Estimated 1947 capital costs of the three sizes of development studied, including costs of dams, reservoirs and conduits, are approximately $9,166,000, $11,972,000 and $13,525,000, respectively. Annual costs are estimated at $390,300, $507,500 and $572,300 for the respective projects.

Lake Hodges

The site considered for a larger Hodges Dam is immediately downstream from the present structure, the proposed new axis being 100 feet downstream at the right abutment and 155 feet at the left abutment. Core drillings were made in connection with construction of the present dam, and the site has since been subjected to examination by competent geologists. The concensus is to the effect that dams of the type considered in present studies would be satisfactorily supported, but that their design should include allowance for seismic forces.

Studies were made of five sizes of dam at the Hodges site, corresponding to a range of reservoir capacities from 104,500 to 340,700 acre-feet. The largest reservoir would be required for complete basin development by Lake Hodges alone, and would require a dam 1,050 feet in length at spillway crest, and 200 feet in height to spillway crest above streambed. The type of dam considered for estimating purposes is a concrete gravity structure with vertical upstream face, and slope of 0.8 horizontal to 1.0 vertical on the downstream face. Width of dam crest is 15 feet. An overflow spillway 400 feet in width is contemplated, to be located at the center of the dam. Enlargement of Lake Hodges would necessitate acquisition of additional lands, largely in San Pasqual Valley, and estimates also include provision for necessary relocation of roads. Yield to the City of San Diego from Lake Hodges is assumed to be pumped to a point two miles south and one-half mile east of Hodges Dam, the filtration plant site mentioned under the discussion of Pamo Reservoir. From there it is conveyed by gravity to Chesterton Tank, near the south edge of Linda Vista Mesa, two miles north of San Diego River, where it is assumed that connection could be made to the existing city system. The amount of water to be so handled is assumed equal to yield developed at Lake Hodges, minus the amount which the City of San Diego is committed by contract to deliver to downstream users. The booster portion of the conduit consists of 1.0 miles of welded steel pipe, and 1.9 miles of concrete-cylinder pipe. Remainder of the line is 16.7 miles in length, and consists of reinforced-concrete-cylinder pipe.

Estimated 1947 capital cost of a Lake Hodges of 340,700 acre-foot storage capacity, including dam, reservoir, pumping plant and conduit, is about $12,735,000, with annual charges of $636,000, including costs of pumping. Indicative of costs of a smaller development is the estimate for a 224,800 acre-foot reservoir, for which 1947 capital cost is approximately $10,919,000, and annual charges $554,400.

Comparison of Surface Reservoirs

In the San Diego region water is so valuable that a system of conservation works resulting in lowest unit cost of yield might not be the most desirable, unless it also fitted into a plan productive of the maximum yield practicable of attainment. It follows that construction of further conservation works in San Dieguito Basin should preferably be under a plan contemplating eventual complete development of water resources of the basin. For purposes of this report, complete conservation development of surface runoff is arbitrarily defined as provision of a sufficient storage capacity to retain without waste to the ocean all runoff of the season of 1914-15, and of the following record flood season of 1915-16.

Comparisons of proposed reservoirs are made on the basis of amount and unit cost of additional yield derived therefrom, above that from the existing Lake Hodges development. The approximately 30 yield-cost studies of individual reservoirs and combinations of reservoirs considered, involve various combinations of storage capacity and methods of operation. Results of the most significant of these studies are summarized in Table 1 (page 20). Neither of the first two proposals listed results in complete conservation development of San Dieguito Basin, and for this reason they are not considered suitable in themselves for a final plan. If complete basin development is achieved exclusively by enlargement of Lake Hodges, additional seasonal 1917-36 firm yield above that of the existing development is estimated at 18,000 acre-feet, at unit cost of about $35.30 per acre-foot. With Sutherland Reservoir built to designed capacity, and Lake Hodges enlarged to accomplish complete conservation development of the basin, estimated additional 1917-36 firm yield of 17,800 acre-feet per season costs about $40.00 per acre-foot. Complete development by construction of reservoirs at the Pamo and Hodges sites results in estimated additional 1917-36 firm seasonal yield of 18,800 acre-feet, but unit cost is considerably greater than under previously discussed plans, amounting to about $48.50 per acre-foot. Likewise, if complete development is achieved through reservoirs at all three of the sites, an estimated 18,800 acre-feet of additional 1917-36 firm seasonal yield is obtained, but at unit cost of $50.40 per acre-foot.

The foregoing comparisons show that Pamo Reservoir should be eliminated from further consideration at this time, because of high unit cost of additional yield under any plan for complete basin development which includes that reservoir. However, a reservoir at the Pamo site may eventually be justified for terminal storage of an imported supply.

Two general plans are left for further consideration, the first consisting of enlargement of Lake Hodges alone, to a capacity of 340,700 acre-feet, and the second involving completion of Sutherland Reservoir to designed capacity together with enlargement of Lake Hodges to 301,700 acre-foot capacity. Estimated additional 1917-36 firm seasonal yield in either case will be approximately 18,000 acre-feet.

TABLE 1

COMPARISON OF RESERVOIRS IN SAN DIEGUITO BASIN

(Based upon Prices Prevailing in April 1947)

Reservoir or Combination of Reservoirs	Storage Capacity in Acre-Feet	Estimated Additional 1917-36 Firm Yield above that of Existing Development in Acre-Feet per Year	Estimated Costs		
			Capital	Annual	Additional 1917-36 Firm Yield per Acre-Foot per Year
Sutherland	36,700	5,000	$ 3,677,000	$163,500	$32.70
Pamo	163,400	14,500	13,525,000	572,300	39.50
Hodges	340,700	18,000	12,735,000	636,000	35.30
Sutherland	36,700				
Hodges	301,700				
Total	338,400	17,800	$14,996,000	$712,600	$40.00
Pamo	163,400				
Hodges	174,400				
Total	337,800	18,800	$21,618,000	$911,600	$48.50
Sutherland	36,700				
Pamo	127,800				
Hodges	174,400				
Total	338,900	18,800	$22,156,000	$947,400	$50.40
Sutherland	36,700				
Hodges	310,000				
Total	346,700	17,800	15,068,000	715,800	40.20
Savings from ten-year delay in enlargement of Lake Hodges*			4,169,000	173,800	9.80
Adjusted costs			$10,898,000	$542,000	$30.40

Note: * - As compared with costs of complete conservation development by initial enlargement of Lake Hodges to 340,700 acre-foot capacity.

As has been stated hereinbefore, it is probable that presently developed water sources of the City of San Diego will provide a sufficient firm supply to meet city requirements up to the year 1960. Only slightly less likely is attainment of maximum safe yield from the present development. Based on the necessity for securing additional water, the need for full conservation development of San Dieguito Basin is therefore not immediate. However, the City has a large investment in reservoir sites in the basin. Furthermore, it has recently filed to appropriate all excess waters of San Dieguito River. Unless reasonable diligence is shown as regards placing these waters to beneficial use, the City's interests may be jeopardized. It follows that the plan to be adopted should permit accomplishment of full conservation development by stages, with initial steps to be taken as soon as possible. Adoption of a plan involving initial completion of Sutherland Reservoir, and subsequent enlargement of Lake Hodges would meet the foregoing requirements.

Allowance should be made for silting at Lake Hodges. This may be accomplished with a reservoir of 310,000 acre-foot capacity, increasing estimated unit cost of additional 1917-36 firm yield under the foregoing staged Sutherland-Hodges development by about $0.20 to $40.20 per acre-foot. Unit cost of this yield is greater than that resulting from initial construction of Lake Hodges alone but, by rational considerations as to financing the staged construction, it is considerably reduced. Since the City may conservatively expect sufficient safe yield from its present development to meet 1960 requirements, it is probable that enlargement of Lake Hodges under a staged program for complete development would follow completion of Sutherland Reservoir by at least ten years. If, in the meantime, construction of the second barrel of the San Diego Aqueduct is undertaken, the period of delay may be much greater. If the period be conservatively taken as ten years, accrued savings in annual costs, over those for initial enlargement of Lake Hodges to the size required for complete basin development, are approximately $4,169,000. By crediting these to costs of the staged development, unit cost of additional 1917-36 firm seasonal yield is about $30.40 per acre-foot.

A rise in cost of power for pumping would further increase the indicated monetary advantage in complete conservation development by staged construction of Sutherland and Hodges reservoirs, rather than by initial enlargement of Lake Hodges. It may be noted that energy costs for required pumping have risen an average of approximately 40 per cent since the estimates for this report were made.

Yield from Underground Reservoirs

Two possible methods of utilizing ground-water basins underlying San Dieguito and San Pasqual valleys were studied. The first consists of their use to supplement surface storage in the salvage of flood waters now wasting to the ocean. The second method involves lowering the ground water below the root zone of native vegetation, thereby reducing losses to consumptive use.

From the standpoint of the City of San Diego, use of the underground reservoir in San Dieguito Valley is not believed to be sufficiently attractive to warrant further consideration. An enlarged Lake Hodges with capacity required for complete conservation development would rarely spill, and draft from the ground waters of San Dieguito Valley would necessarily be replenished almost exclusively by minor local runoff. Yield of the underground basin would be greatly reduced. Furthermore, it is probable that appreciable lowering of the water table, especially near the coast, will result in contamination due to sea water infiltration. However, some further development of San Dieguito Valley ground water by overlying landowners may be practicable.

It has been estimated that utilizable storage capacity of the gravels beneath San Pasqual Valley is about 13,000 acre-feet. However, if a surface reservoir with capacity required for complete conservation development is constructed at Lake Hodges, over half of the San Pasqual Valley ground-water basin will be drowned more than 50 per cent of the time. It is apparent that surface and underground storage developments are largely incompatible. Despite this, a total amount of approximately 13,000 acre-feet is available from San Pasqual Valley ground waters, as an emergency supply during drought periods.

Studies of consumptive use show that a moderate amount of water may be salvaged from San Pasqual Valley by a program of pumping designed to maintain the water table at levels below the root zone of native vegetation. Based upon field surveys of irrigated

crops and native vegetation, and upon estimated unit values of consumptive use, it is in-
dicated that an average of approximately 8,800 acre-feet of water is consumed seasonally
in San Pasqual Valley. By lowering the ground water eight feet below its normal level,
seasonal use would be reduced to 4,050 acre-feet, with no change in consumptive use of
presently irrigated agricultural crops. It is probable that in actual practice, however,
the salvage from natural losses in San Pasqual Valley would be only about 50 per cent ef-
ficient. If the City of San Diego, in securing water rights required for construction of
a larger Lake Hodges, acquires the entire San Pasqual valley floor, it can probably con-
serve an estimated 2,000 acre-feet per season by reducing consumptive use of native vege-
tation, and at the same time allow full irrigation of presently irrigated lands in the
upper end of the valley.

Flood Control Works

Damages from floods in San Dieguito Basin are largely confined to San Pasqual
and San Dieguito valleys, in both of which overflow areas are principally agricultural in
nature. Out of a total of about 2,100 acres in San Pasqual Valley, 485 are irrigated,
and 1,250 are given over to native salt grass pasture. In the approximately 2,800 acres
comprising the floor of San Dieguito Valley, culture of irrigated crops is confined to
about 1,000 acres, largely in the upper end of the valley. At the lower end of this val-
ley, however, in a filled area that was once tidal marsh, the Del Mar Turf Club and San
Diego County Fair grounds are subject to inundation from a large flood, while highway and
railway crossings of the river would be damaged. A few beach homes in the vicinity might
also be damaged or destroyed. Both San Pasqual and San Dieguito valleys are narrow in
relation to length of river channel. Stream channels are characterized by low banks, with
waterways generally choked by brush, so that even moderate floods overflow portions of the
transversely level valley floors, and major floods menace the entire areas.

Preliminary study indicated that protection of these valleys by levees or chan-
nel improvements is not economically feasible at this time. Any flood control reservation
of storage space in reservoirs under consideration in this investigation would reduce
their catchment for conservation, and could only be justified if protection were afforded
a highly developed area. Such is not the case at this time. Therefore, further study of
flood control in San Dieguito Basin was confined to evaluation of control derived from
reservoirs under consideration, incidental to their operation for conservation. No attempt
was made to determine feasibility of providing reservoir storage space exclusively for
flood control purposes, supplementary to requirements for conservation.

Probable size and frequency of flood flows at Sutherland, Pamo and Hodges dam
sites were determined by standard methods, based upon recorded floods since 1906, the
greatest of which occurred on January 27, 1916. Mean flood hydrographs were computed for
each of the three sites, based upon available information in connection with floods of
record.

A reservoir at the Sutherland site, resulting from completion of the dam as
originally planned, could not be depended upon for appreciable reduction in flood damages
in San Pasqual Valley, nor in areas downstream therefrom. Although the watershed above
Sutherland Dam contributes about one-half of the flood waters reaching San Pasqual Valley,
capacity of the reservoir would be small as compared with runoff during flood seasons.
With the reservoir operated for conservation, it might be full at time of peak flows, and
with drum gates there could be no storage above the conservation pool level. Possible

faulty gate operation might actually increase downstream peak flows. Furthermore, under the recommended plan for complete conservation development of San Dieguito Basin, the large reservoir proposed at the Hodges site would inundate nearly 60 per cent of the floor of San Pasqual Valley, and benefits from flood control at Sutherland would be confined to the remaining area. The enlarged Lake Hodges in itself would provide a large measure of flood protection to San Dieguito Valley, and render insignificant any effects attributable to Sutherland Reservoir.

A relatively small amount of flood control storage reservation in Pamo Reservoir would materially reduce crest flood flows in San Pasqual Valley. Even without such reservation, a conservation reservoir of 163,400 acre-foot storage capacity would reduce the once in 100-year flood crest discharge from 67,000 to 31,000 second-feet, by temporary storage above the spillway lip. However, under any plan for complete conservation development involving a reservoir at Pamo, Lake Hodges would have to be enlarged in order to conserve runoff originating between Pamo and Hodges. Such enlargement would inundate about one-half of the floor of San Pasqual Valley, and benefits from flood control at Pamo would be confined to the remaining area. The enlarged Lake Hodges in itself would provide a large measure of downstream flood protection, minimizing flood control effects of Pamo Reservoir in San Dieguito Valley. Finally, comparative costs of additional yield do not favor conservation development at Pamo. Flood control benefits that may be attributed to the development are insufficient to alter this relationship.

In connection with Lake Hodges it was found that storage capacity equal to 22 per cent of mean daily flood volume would be required to regulate crest flood flows to 50 per cent of their unregulated rate. This would amount to a storage reservation of 23,000 acre-feet for a once in 100-year flood, with peak flow of 88,400 second-feet. However, the reservoirs under consideration in this study should be operated for conservation, and the provision of any storage at Lake Hodges exclusively for flood control purposes may not be justified, in view of the incidental protection afforded by a large conservation reservoir.

Any reservoir at Hodges with capacity of 225,000 acre-feet or more, operated solely for conservation, would reduce peak flow of the once in 100-year flood by at least 43 per cent, the reduction being achieved by ponding or temporary storage above the spillway crest. In addition to this direct reduction of flood flows, there would be small probability of a large flood occurring at a time when a large conservation reservoir at Lake Hodges was full. Probability studies indicate that a once in 25-year flood at Hodges Dam could be accommodated within available reservoir space of a 340,700 acre-foot reservoir 84 years out of 100, on the average. A once in 50-year flood could be similarly accommodated 78 years out of 100, on the average. Furthermore, it was determined by statistical methods that with a 310,000 acre-foot reservoir operated exclusively for conservation purposes, the frequency of occurrence of a normal once in 25-year flood would be reduced to once in 215 years, at a point just below the dam. Similarly, a normal 100-year flood would occur, on the average, only once in 440 years.

San Diego River Basin

A plan for complete development of the waters of San Diego River, including flood control as well as conservation, was presented in Bulletin No. 48.* The City of San

* Bulletin No. 48, "San Diego County Investigation", Division of Water Resources, State Department of Public Works, 1935.

Diego has subsequently constructed San Vicente Reservoir, a conservation feature of the 1935 plan, but to a smaller storage capacity than was therein proposed. No steps have been taken to provide a conservation reservoir in Mission Gorge, as was also proposed in Bulletin No. 48. Consideration of San Diego River Basin during the current investigation was limited to further study of possible Mission Gorge reservoirs, and to increasing the size of San Vicente Reservoir to provide additional storage capacity, as suggested by the City of San Diego.

Conservation Reservoirs in Mission Gorge

Mission Gorge No. 2 dam site is in the upper end of Mission Gorge, about 3,100 feet downstream from Old Mission Dam. Mission Gorge No. 3 dam site is a further 1.8 miles downstream, while Mission Gorge No. Zero dam site is about 1,000 feet upstream from Old Mission Dam. Sites Nos. 2 and 3 were extensively studied for Bulletin No. 48, wherein it was shown that the proposed No. 2 reservoir was the more favorable economically. Mission Gorge Reservoir No. Zero was not considered in that report.

Current studies of the Mission Gorge reservoirs are based upon later and more accurate survey data than were available in 1935, and include cost data corresponding with April 1947 prices. In the case of Mission Gorge Reservoir No. 2, land acquisition costs are estimated to have risen from $600,000 to about $912,000 since 1935, while for Mission Gorge Reservoir No. 3 the estimated increase is from $180,000 to about $211,000. Estimated land and rights of way costs of the Mission Gorge No. Zero site are the same as those for the No. 2 site.

Mission Gorge Reservoir No. Zero

The dam studied for this reservoir consists of a concrete gravity section, 860 feet in length across the river channel, with an additional 600 lineal feet of rolled earth-fill embankment extending to the right abutment. Height of dam from streambed to spillway crest is 58 feet, forming a reservoir with capacity of 23,700 acre-feet. An overflow spillway is planned in the concrete gravity portion of the dam. If operated coordinately with existing Cuyamaca, El Capitan and San Vicente reservoirs on San Diego River, it is estimated that the reservoir will provide additional safe seasonal yield of 1,900 acre-feet. No geologic exploration of Mission Gorge No. Zero dam site was made, but visual inspection indicates that suitable foundations can be found for a dam of moderate height. Before final decision to utilize this site is made, systematic foundation exploration should be conducted. Based upon April 1947 prices, estimated capital cost of the dam and reservoir is about $3,237,000, and annual costs are estimated at $136,100.

Mission Gorge Reservoir No. 2

The dam considered for this site is identical with that proposed in Bulletin No. 48, and consists of a concrete gravity structure with overflow spillway. Storage capacity is 29,200 acre-feet at the spillway lip, 92 feet above streambed. If operated coordinately with existing Cuyamaca, El Capitan and San Vicente reservoirs, it is estimated that the reservoir will provide additional safe seasonal yield of 2,300 acre-feet. Estimated capital cost, based upon April 1947 prices, is approximately $3,586,000, while annual costs are estimated at $150,000. These constitute increases from $2,143,000 and $137,800 for corresponding 1935 cost estimates.

Mission Gorge Reservoir No. 3 with Concrete Gravity Dam

The dam considered for the No. 3 site in this study is identical with that studied in Bulletin No. 48, of concrete gravity construction, straight in plan and with

spillway in the crest of dam. Height of dam from streambed to spillway crest is 216 feet.
Capacity of the reservoir is 29,200 acre-feet, and additional seasonal safe yield, when
operated coordinately with existing Cuyamaca, El Capitan and San Vicente reservoirs, is
estimated at 2,600 acre-feet. Estimated capital cost, based upon April 1947 prices, is
about $6,157,000, and estimated annual costs are $259,000. Corresponding estimates in
1935 were $3,666,000 and $237,100, respectively.

Mission Gorge Reservoir No. 3 with Concrete Arch Dam
In an effort to determine the most economical solution to the problem of a dam
at the No. 3 site, a preliminary design was made for a variable-radius arch dam with
fixed-crest overflow spillway. Geologic studies indicate that conditions at the site are
not favorable to concrete arch construction. Furthermore, the topography is not ideal
for an arch dam, since the canyon slopes are flatter than desirable, and contours paral-
lel the thread of the stream. To meet these adverse conditions requires heavy excavation.

Height of the arch dam, like that of the gravity structure considered for the
same site, is 216 feet from streambed to spillway crest. Gravity abutments at the ends
of the upper portions of the arch provide for thrust, which otherwise would not be satis-
factorily transmitted to the canyon walls. The plan provides for a sliding joint at an
elevation 20 feet above streambed, the dam below this elevation being designed to support
the water load by gravity action. Estimated capital cost, based upon April 1947 prices,
is about $5,242,000, and estimated annual costs are $220,000.

Comparison of Reservoirs
If operated coordinately with existing Cuyamaca, El Capitan and San Vicente res-
ervoirs, it is estimated that additional safe seasonal yield to be derived through con-
struction of one of the heretofore described Mission Gorge reservoirs, No. Zero, No. 2 or
No. 3, would be 1,900 acre-feet, 2,300 acre-feet or 2,600 acre-feet, respectively. It is
further estimated that respective unit costs of this yield, based upon April 1947 prices,
would be about $71.60 for Mission Gorge Reservoir No. Zero, $65.20 for Mission Gorge Res-
ervoir No. 2, and $84.60 per acre-foot for Mission Gorge Reservoir No. 3 with a concrete
arch dam. It is apparent that Mission Gorge Reservoir No. Zero is less desirable, both in
amount of additional safe yield and in unit cost of that yield, than is a reservoir at the
Mission Gorge No. 2 site. It is also apparent that neither changed conditions since 1935,
nor substitution of an arch dam for a gravity structure at the No. 3 site, alter the con-
clusion reached in Bulletin No. 48, to the effect that Mission Gorge Reservoir No. 2 is
more favorable than No. 3 for conservation purposes. However, if it should ever be found
desirable to provide a recreational lake in Mission Gorge, the fact that the No. 3 site
comprises canyon storage with materially lower evaporation losses than upstream sites
should be considered. Economic analyses of such dual purpose developments in Mission
Gorge, which would involve higher dams to provide storage reservations for recreation as
well as necessary conservation, have not been included in the present studies.

Enlarged San Vicente Reservoir
Although the existing San Vicente Reservoir has sufficient storage capacity for
complete conservation of its tributary runoff, its enlargement for storage of foreign wa-
ter may be desirable because of favorable geographical, climatological and storage charac-
teristics of the site. Officials of the City of San Diego visualize a need for a strategi-
cally located reserve supply, for use in case of unprecedented drought, interruption of
the Colorado River supply, or other unforseen disaster. They have suggested that an en-
larged San Vicente Reservoir of 250,000 acre-foot capacity would provide 150,000 acre-feet

of storage, for the combined purposes of conserving San Vicente Creek runoff, storing San Diego River water transferred from the less efficient El Capitan Reservoir, and storing San Dieguito Basin water imported from Sutherland Reservoir. The remaining 100,000 acre-feet of storage capacity in San Vicente Reservoir would be reserved for Colorado River water, an amount sufficient to meet estimated ultimate water requirements of the City for nearly a year.

San Vicente Dam was constructed with the consideration in mind of raising it from its present 190 feet to 310 feet in height at some future date, by adding concrete on the downstream side. While grouting was carried out to the extent necessary for the higher dam, no stepping or other special treatment was given the downstream face. Special methods will be required to properly place additional concrete on the old surface, and at the same time provide for shrinkage due to cooling and settling. A further problem is that of securing a good seal at the upstream face between the old structure and the raise. The surface between the new and old concrete must be thoroughly drained, and inspection galleries provided to permit inspection of such drainage.

The plan of enlargement contemplates making the upstream face of the enlargement vertical and battering the downstream face at a slope of 0.8 to 1. Details of crest, spillway and outlet works would be reconstructed similarly to those now existing. In order to attain the desired storage capacity of 250,000 acre-feet the spillway would be raised to elevation 768 feet, or an increase of 118 feet above the present dam. Height of the enlarged dam would be 308 feet to spillway crest above streambed.

Based upon prices prevailing in April 1947, it is estimated that capital cost of the foregoing enlargement of San Vicente Reservoir is about $8,489,000. Annual costs are estimated at $352,600.

Conclusions

Under terms of the agreements authorizing the present investigation, its purpose has been to determine the best program of development of a water supply for the City of San Diego on the San Dieguito and San Diego rivers. In accordance with this purpose, and based upon results of the investigation, the following conclusions have been reached:

1. Safe yield from the present water supply development of the City of San Diego, including the Colorado River supply, is sufficient to meet probable increasing demands until 1960, forecast at 62.5 million gallons per day, even under extremely conservative assumptions as to interim runoff. Furthermore, there is reasonable expectation that reservoirs will fill prior to 1960, and that full estimated safe yield of 80.8 million gallons per day may be attained.

2. Ultimate water requirements for the present incorporated area of the City of San Diego, including allowance for military and naval establishments, will probably be about 100 million gallons per day, or 112,000 acre-feet seasonally.

3. In the interest of conservatism as regards a municipal water supply of vital necessity, a supplementary supply should be made available to the City of San Diego at the earliest practicable date.

4. During the 50-year normal period 1891-92 to 1940-41, inclusive, seasonal precipitation in San Dieguito Basin averaged an estimated 19.63 inches in depth, or a total amount of about 363,000 acre-feet. Resultant seasonal runoff at three principal dam sites in the basin, Sutherland, Pamo and Hodges, would have averaged an estimated 15,600 acre-feet, 25,000 acre-feet and 40,700 acre-feet, respectively, under present conditions of culture and development.

5. Estimated seasonal utilization of water originating within San Dieguito Basin averages about 13,500 acre-feet at the present time, and will probably increase to approximately 34,000 acre-feet under conditions of ultimate development. The City of San Diego, which now receives 3,070 acre-feet, on the average, from San Dieguito Basin each season, should realize an estimated 19,000 acre-feet seasonally under the recommended complete conservation development of the basin, the remainder after ultimate requirements of other users of water from the basin have been satisfied.

6. Waters of San Dieguito Basin lost to higher forms of economic utilization are estimated to average about 350,000 acre-feet seasonally under present conditions, including an undetermined amount consumed by natural grasses used for grazing. Losses consist of consumptive use by other native vegetation (including evaporation from soil and natural water surfaces), outflow to the ocean, and evaporation from reservoirs. Any salvage from these losses must be principally effected from present outflow to the ocean, estimated to average approximately 25,000 acre-feet per season.

7. Estimated safe seasonal yield from Lake Hodges, the only existing water supply development of consequence on San Dieguito River, would have been 6,700 acre-feet during the extreme ten-year drought from 1895-96 to 1904-05, inclusive. During the more extended but less severe drought from 1916-17 to 1935-36, inclusive, 1917-36 firm seasonal yield would have been an estimated 11,400 acre-feet.

8. Construction of further conservation works in San Dieguito Basin should be under a plan contemplating eventual complete development of its water resources. Complete development of surface runoff is arbitrarily defined as that which would have conserved the runoff of 1914-15 and prevented spill at Hodges Dam during the ensuing record flood season of 1915-16. This necessitates total storage capacity within the basin estimated at approximately 340,000 acre-feet, with at least 174,400 acre-feet at Lake Hodges. Resultant 1917-36 firm seasonal yield is estimated at about 30,000 acre-feet, while safe yield varies from 86 to 95 per cent of that amount, dependent upon disposition of storage. Under various combinations of storage capacity, as divided between Hodges, Pamo and Sutherland reservoirs, 1917-36 firm yield is approximately the same, provided that in each case Lake Hodges has sufficient capacity to prevent spill.

9. Assuming that existing work has been done in accordance with indicated contract plans and specifications, the completion of Sutherland dam and reservoir to designed capacity of 36,700 acre-feet is practicable from the engineering standpoint. Including a gravity conduit to transmit its yield to San Vicente Reservoir, its estimated capital cost, based on 1947 prices, is about $3,677,000, with annual charges of $163,500.

10. Construction of an earth-fill dam at the Pamo site, of sufficient size to completely conserve runoff from the tributary drainage area, is practicable. Such a reservoir would have an estimated storage capacity of 163,400 acre-feet and, including a conduit to transmit its yield to Chesterton Tank on Linda Vista Mesa, would cost an estimated $13,525,000, based upon 1947 prices. Annual costs would amount to an estimated $572,300. However, Pamo Reservoir should be eliminated from further consideration at this time, because studies indicate that plans for complete basin development which include that reservoir result in relatively high unit cost of additional yield. The site should be retained for possible future terminal storage of an imported water supply for the San Diego region.

11. Enlargement of Lake Hodges, to approximately 340,000 acre-feet of storage capacity required for complete basin development, by construction of a concrete gravity dam immediately downstream from the present structure, is practicable. Such a dam and reservoir, together with conduit and pumping plant to deliver yield at Chesterton Tank on Linda Vista Mesa, will involve an estimated capital outlay of $12,735,000, based upon 1947 prices. Estimated annual charges are $636,000.

12. If complete conservation development of San Dieguito Basin is achieved exclusively by enlargement of Lake Hodges, an estimated additional 18,000 acre-feet per season of 1917-36 firm yield will be derived above that of the existing development, or a total of 29,400 acre-feet, at estimated unit cost of about $35.30 per acre-foot.

13. If complete conservation development of San Dieguito Basin is achieved through completion of Sutherland Reservoir, together with enlargement of Lake Hodges, an estimated 17,800 acre-feet of additional 1917-36 firm yield will be attained seasonally, at estimated cost of about $40.00 per acre-foot. However, if an additional 8,300 acre-feet of reservoir space at Lake Hodges is provided for silt storage, and the foregoing plan is constructed by stages, with enlargement of Lake Hodges following completion of Sutherland Reservoir by a period of ten years, as is considered probable, unit cost of additional 1917-36 firm yield from the combined development will be reduced to an estimated $30.40 per acre-foot.

14. Despite the present sufficiency of its water supply, it is to the interest of the City of San Diego to undertake development of additional conservation works in San Dieguito Basin in the near future, in order to preserve the City's large investment in reservoir sites and maintain recent city filings on excess waters of San Dieguito River. Practical as well as economic considerations indicate that development should be achieved by a program of staged construction of Sutherland and Hodges reservoirs for eventual complete basin development, with initial completion of Sutherland Reservoir, and subsequent enlargement of Lake Hodges to 310,000 acre-foot storage capacity. It is estimated that an enlarged Lake Hodges should be completed about ten years in advance of anticipated requirement for supplementary yield therefrom.

15. Under conditions of ultimate conservation development, the City of
San Diego can salvage an estimated 2,000 acre-feet per season, on the aver-
age, from water now lost by consumptive use of native vegetation and evapora-
tion from soil and natural water surfaces in San Pasqual Valley. During
drought periods an emergency supply of water, in total amount estimated at
approximately 13,000 acre-feet, can be obtained from the ground-water basin
underlying San Pasqual Valley.

16. Flood damages in San Dieguito Basin are largely confined to San
Pasqual and San Dieguito valleys, which areas are narrow relative to reaches
of river involved, and therefore not subject to economic protection by means
of levees or channel improvements. Neither can their limited size nor minor
development justify reservoir control of floods as an end in itself.

17. Construction of Sutherland, Pamo or Hodges reservoirs for conserva-
tion purposes will result in varying degrees of downstream flood protection,
through reduction in peak flood flows by catchment in available empty reser-
voir space and by ponding above spillway elevations. In the case of the
planned Sutherland Reservoir such benefits will be minor and undependable.
Pamo Reservoir will appreciably lower peak flows in San Pasqual Valley, but
benefits will be minimized under any plan for complete conservation develop-
ment of the basin, because over half of San Pasqual Valley will then lie within
the Lake Hodges flow line, and Lake Hodges itself will provide a large measure
of downstream flood protection. However, if a Lake Hodges with capacity of
225,000 acre-feet or more is operated solely for conservation purposes, peak
flow of a once in 100-year flood will be reduced by at least 43 per cent.
Furthermore, floods will usually be partly absorbed by vacant storage space
in a large conservation reservoir at Lake Hodges, so that probable frequency
of occurrence of given flood flows at all points downstream will be greatly
reduced. A portion of capital costs of an enlarged Lake Hodges may properly
be charged to flood control.

18. The dam and reservoir proposed in Bulletin No. 48 for the No. 2
site on Mission Gorge on San Diego River is still found to be the most favor-
able plan for conservation development at Mission Gorge. Based upon 1947
prices, its capital cost is estimated at about $3,586,000, with annual costs
of $150,000. Based upon sustained supply during the 1896-1905 drought, safe
seasonal yield to be derived from its construction, above that of the exist-
ing San Diego River development, is estimated at 2,300 acre-feet, at a unit
cost of $65.20 per acre-foot. Comparable 1947 unit cost of the estimated
2,600 acre-feet of additional safe seasonal yield to be obtained from Mission
Gorge Reservoir No. 3, under the plan described in Bulletin No. 48, is esti-
mated at $99.60 per acre-foot, while that for a concrete arch dam at the No. 3
site is estimated at $84.60 per acre-foot. A reservoir at the newly proposed
Mission Gorge No. Zero site will produce an estimated 1,900 acre-feet of addi-
tional safe seasonal yield, at estimated cost of about $71.60 per acre-foot.

19. Enlargement of San Vicente Reservoir to provide 250,000 acre-feet
of storage capacity, as suggested by officials of the City of San Diego, is
practicable from the engineering standpoint. Based upon prices prevailing
in April 1947, capital cost of such enlargement is estimated at about
$8,489,000, with annual charges of $352,600.

Recommendations

       With respect to development of a water supply for the City of San Diego on the San Dieguito and San Diego rivers, it is recommended:

       1. That Sutherland Dam be completed substantially as originally designed, to provide a reservoir with storage capacity of 36,700 acre-feet, and that a gravity conduit be constructed to transmit water yield to San Vicente Reservoir, the project to be undertaken as soon as is practicable.

       2. That an enlarged Hodges Dam, to provide a reservoir with the estimated 310,000 acre-feet of storage capacity required in conjunction with Sutherland Reservoir for complete conservation development of surface runoff in San Dieguito Basin, together with necessary pumping plant and conduit to transmit water yield to the City of San Diego, be constructed approximately ten years in advance of anticipated need for supplementary yield therefrom.

       3. That a program be initiated as soon as is practicable for acquisition of lands, easements and rights of way necessary for construction of an enlarged Lake Hodges with storage capacity of 310,000 acre-feet.

       4. That a system of pumping wells and collecting pipe line in San Pasqual Valley, of sufficient capacity to lower the water table and effect salvage from natural consumptive use, be constructed when growing water demands of the City of San Diego indicate a need for such supplementary yield.

       5. That Federal assistance be sought in construction of an enlarged Hodges dam and conservation reservoir, on the basis and to the extent of resultant reduction in downstream flood damages.

       6. That Mission Gorge Dam No. 2, to provide a reservoir with storage capacity of 29,200 acre-feet as required for complete conservation development of surface runoff in San Diego River Basin, be constructed when growing water demands of the City of San Diego indicate a need for such supplementary yield.

CHAPTER III

WATER REQUIREMENTS OF CITY OF SAN DIEGO

History and description of the City of San Diego and its water system have been
adequately covered in prior reports, and will be detailed herein principally as regards
recent developments, particularly during and since the war period.

Although the mild climate and attractive setting had for many years drawn per-
manent residents and wealth to San Diego, and made it known as an all-year tourist
resort, the City, even prior to World War II, was important as an agricultural, mercan-
tile, industrial and shipping center. A further large factor in its economy was the
presence of extensive naval installations. A modest aircraft manufacturing industry ex-
isted, but commercial fishing and canning, boat building, and coastal and foreign ship-
ping were also important activities. After our entry into the war in December 1941, the
Federal establishments, both military and naval, were expanded many times over, and with
the mushrooming aircraft industry dominated the economy of the area. Private shipping
from the port ceased entirely, but governmental shipping increased as the City became a
base of supply for naval and marine activities in the Pacific. Since the end of hostili-
ties in August 1945, the nature of the City's economy has again undergone revolutionary
change, with both military and naval activities curtailed, and the aircraft industry ac-
tive but at greatly reduced scale. However, increased activity has been experienced in
public and private construction. New industries and commercial firms are entering the
area, and boat building, fishing, canning and the tourist trade are again important, in
large measure replacing wartime activities. Commercial shipping from the port of San
Diego has not been resumed to any appreciable extent.

The City of San Diego, with a prior history of rapid growth, experienced an un-
precedented influx of population attendant with its expanded activities during World War
II. According to the Federal census, population had increased from 147,995 to 203,341
between 1930 and 1940. In February 1946, a special count by the Bureau of the Census
showed a population of 362,658, with some 64,000 additional residents in the metropolitan
area contiguous to the City. No authentic figures are available with respect to present
(1948) population.

Service area of the City of San Diego's water system consists principally of
the 95.5 square miles within the city limits. During the war, large naval and military
establishments outside its boundaries were served by the City, but these no longer con-
stitute an important water demand. The City is contractually obliged to serve water for
the City of Coronado upon demand, but only very minor delivery is being made at the pres-
ent time. The San Diego city limits include an area extending from a mile south of Del
Mar, southerly along the coast for nearly 20 miles, and inland a distance as great as
eight miles. Included are the communities of La Jolla, Pacific Beach, Mission Beach,
Ocean Beach, Point Loma and Linda Vista, but the main urban portion of the City covers an
area of about 15 square miles lying around, and to the east of the northern half of San
Diego Bay.

Present Water Supply

Until recent date, the City of San Diego has utilized only water from nearby sources of supply, either surface streams or ground-water basins within San Diego County. Of these, the surface sources have been by far the more important, and no water has been pumped from underground basins for a number of years. In late 1947 a new source of supply, that of imported water from the Colorado River, became available to the City, and now constitutes a major part of its water assets.

Local Surface Sources and Development

The City of San Diego obtains water from surface sources within the County in the watersheds of Cottonwood Creek, Otay River, San Diego River and San Dieguito River. Each of these is developed by conservation reservoirs, diversion works and transmission lines, as is shown on Plate I, "Sources of Supplies and Transmission Lines of Water System of San Diego Metropolitan Area". Characteristics of the city reservoirs are listed in Table 2.

TABLE 2

RESERVOIRS OF CITY OF SAN DIEGO

Reservoir	Location	Type of Dam	Spillway Type	Height above Streambed in Feet	Elevation of Lip in Feet	Capacity in Second-Feet	Drainage Area in Square Miles	Storage* Capacity in Acre-Feet	Safe Yields** Available to City — in acre-Feet per Year	Safe Yields** Available to City — in Million Gallons per Day	Remarks *Without consideration of silting. **Estimated by City of San Diego on basis of no deficiency during drought period, 1895-1905, inclusive.
STORAGE											
Morena	Cottonwood Creek	Rock fill	Side channel	169	3,039	50,000	120	61,200	5,000	5.0	Spillway gates removed and lip raised two feet in 1946.
Barrett	Cottonwood Creek	Gravity-concrete	Overflow with gates	142	1,615	70,000	130	42,900	5,400	4.	
Upper Otay	Proctor Valley Creek	Constant radius concrete arch	Overflow	72	550	3,460	12	2,800			Safe yield included in Lower Otay.
Lower Otay	Otay River	Gravity-concrete	Overflow with gates	140	491	43,000	95	50,300	4,300	4.	Drainage area includes Upper Otay.
El Capitan	San Diego River	Hydraulic and rock fill	Side channel	197	750	102,000	190	116,900	11,200	10.0	Completed in 1935. Storage capacity of 10,000 acre-feet assigned to La Mesa, Lemon Grove & Spring Valley Irrigation District.
San Vicente	San Vicente Creek	Gravity-concrete	Overflow	197	650	31,000	75	90,200	5,900	5.5	Completed in 1943.
Hodges	San Dieguito River	Multiple concrete arch	Overflow	115	315	90,000	303	37,700	3,300	3.4	Safe yield of 3,400 acre-feet per year assigned to Committees.
TOTALS ------ STORAGE RESERVOIRS ----------------------							916	402,000	35,700	31.7	Total storage capacity of 390,000 acre-feet available to City.
REGULATING											
Murray	Tributary of Alvarado Canyon	Multiple concrete arch	Siphon	107	541	1,000	3.7	5,980	—	0	Owned by La Mesa, Lemon Grove & Spring Valley Irrigation District. Storage capacity of 5,000 acre-feet assigned to City.
San Dieguito	Little San Elijo Creek	Multiple concrete arch	Siphon	41	250	1,230	1.2	1,128	0	0	
Chollas	Tributary of Chollas Creek	Earth fill	None					278	0	0	
22 basins or tanks	Throughout service area	Concrete or steel						100	0	0	
TOTALS ------ REGULATING RESERVOIRS ----------------------------								7,386			Total storage capacity of 7,506 acre-feet available to City.
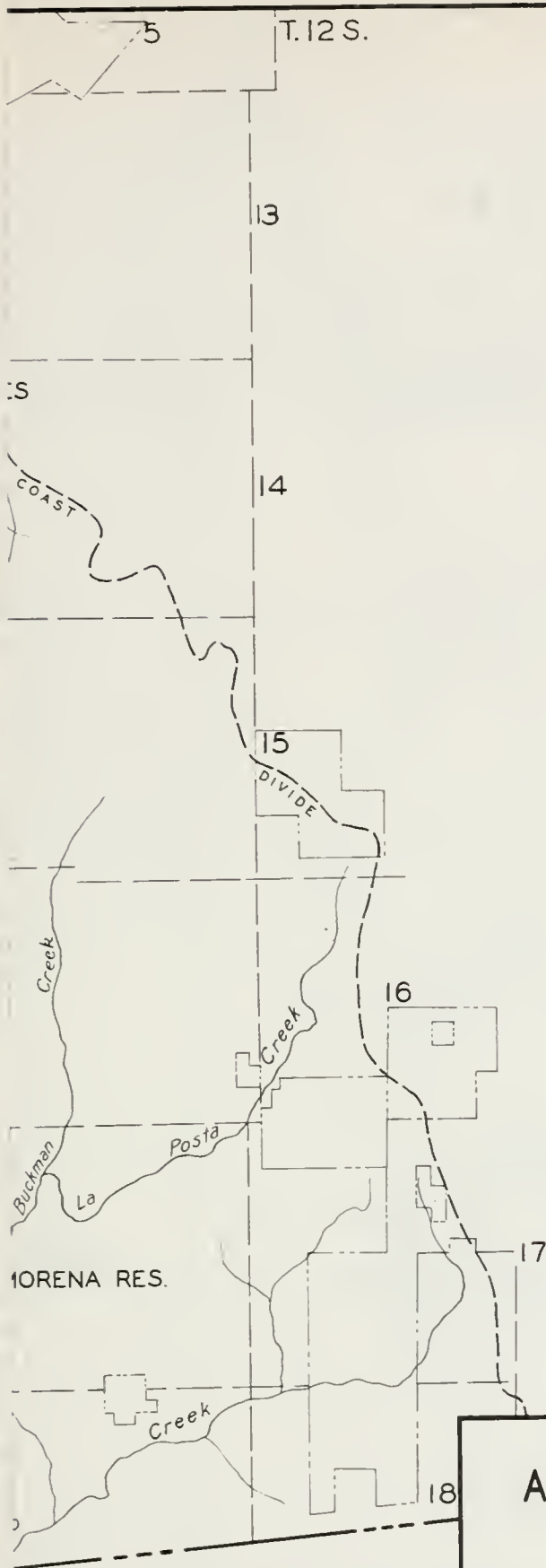
PLATE I

SOURCES OF SUPPLIES
AND TRANSMISSION LINES
OF
WATER SYSTEM
OF
SAN DIEGO METROPOLITAN AREA

Scale of miles

PLATE I

R. I W R. I E. T. 12 S.

4   3   2   2   3   4   5

13

14

15

16

17

18

PACIFIC OCEAN

JOINT GRAVITY PIPE LINE

SAN DIEGUITO RES.

LAKE HODGES RES.

SAN PASQUAL VALLEY UNDERGROUND BASIN

Santa Maria Creek

River

Creek

LOCKWOOD MESA RES.

HODGES CONDUIT

24 26 27

Escondido Creek

San Dieguito River

Del Mar

UNDERGROUND BASIN

LOCKWOOD MESA—TORREY PINES PIPE LINE

SAN DIEGO AQUADUCT

Boulder Creek

CUYAMACA RES.

PACIFIC COAST

Los Penasquitos Creek

Creek

POWAY TUNNEL

FIRE HILL TUNNEL

Vicente Creek

EL CAPITAN RES.

TORREY PINES RES.

SAN VICENTE TUNNEL

SAN VICENTE RES.

SAN VICENTE PIPELINE NO. 1—42-1/2"

SAN VICENTE LINE NO. 2—48"

San Diego River

48"

Canyon

City of

LA MESA—SWEETWATER EXTENSION (S. D. CO. WATER AUTHORITY)

EL MONTE PUMP PLANT

36"

EL CAPITAN LINE

UNDERGROUND BASIN OLD MISSION DAM

WELL FIELDS

L.M.,L.G.& S.V. IRR. DIST. CONDUIT

River

EL MONTE LINE

MISSION DAM SITE NO. 3

ALVARADO PUMP PLANT

MISSION DAM SITE NO. 2

MISSION DAM SITE NO. ZERO

MURRAY LINE

Rose Canyon

Mission Bay

CHESTERTON TANK

GROSSMONT TUNNEL

LOVELAND RES.

Pine Creek

Creek

San Diego

UNDERGROUND BASIN

MURRAY RES.

42" 48"

48"

ALVARADO LINE—36"

PROPOSED TROJAN LINE—54"

GROSSMONT RES.

EUCALYPTUS RES.

Sweetwater River

Buckman Creek

La Posta Creek

DIVIDE

MISSION VALLEY LINE 24"

UNIVERSITY HTS. RES.

30"

36"

CHOLLAS WYE

CHOLLAS RES.

San Diego Bay

BONITA LINE CONNECTION

BONITA LINE

National City

UNDERGROUND BASIN

SWEETWATER RES.

UPPER OTAY RES.

BARRETT RES.

Cottonwood Creek

MORENA RES.

Chula Vista

OTAY LINE

BONITA WYE

DULZURA CONDUIT

Creek

Dulzura Creek

16"

24"

Otay River

JUDSON RES.

CORONADO WYE

30"

40"

OTAY RES.

SAVAGE DAM

Sweetwater

Cottonwood Creek

Campo Creek

WELL FIELDS

20"

HIGHLAND RES.

UNDERGROUND BASIN

CORONADO LINE

Tia Juana River

UNITED STATES

MEXICO

Older features of the reservoir system have been described in earlier reports. However, two significant changes have been made in the past decade, namely, the construction of San Vicente Reservoir, and the alteration of the spillway at Morena Dam. The first cited work began in 1941 and was completed in 1943. San Vicente Dam, a gravity type, concrete-masonry structure, is located about 20 miles northeast of downtown San Diego, on San Vicente Creek, a tributary of San Diego River. It is straight in plan, 190 feet in height above streambed, and 980 feet in length at the crest. Storage capacity of the reservoir at spillway elevation of 650 feet, 12 feet below the dam crest, is 90,200 acre-feet. The overflow spillway in the central portion of the dam is 275 feet long and has a capacity of 31,000 second-feet. With a drainage area of 75 square miles, safe yield under combined operation with El Capitan Reservoir is estimated by the City at 5,900 acre-feet seasonally, or 5.3 million gallons per day, on the basis of a sustained water supply throughout the severe drought period from 1896 through 1905. Water is released from San Vicente Reservoir by means of a semi-circular outlet tower on the upstream face of the dam. Five valved ports, 30 inches in diameter, spaced at 30-foot vertical intervals, control entry of water into the tower, from which it discharges through three 36-inch diameter pipes laid in the base of the dam. These pipes are controlled by valves at the downstream toe.

As a result of alteration in the spillway of the dam, capacity of Morena Reservoir was reduced by 4,600 acre-feet in 1946. The work was undertaken in interests of safety, and involved removal of gate structures to permit free passage of flood flows. At the same time the spillway lip was raised two feet to elevation 3,039 feet. Capacity at spillway lip is now 61,200 acre-feet, neglecting losses due to silting of the reservoir since construction.

Aggregate conservation storage available to the City of San Diego is 398,000 acre-feet. Safe yield available to the City, defined as sustained supply without deficiency during the record 1896-1905 drought, is estimated by the City at 35,700 acre-feet per season, or 31.9 million gallons per day. These figures do not take into consideration loss of capacity through silting of reservoirs since construction.

Local Underground Sources

Prior to construction of El Capitan Dam in 1936, the City of San Diego pumped a portion of its water supply from underground basins along San Diego River, but the practice was discontinued when the dam was placed in operation. The wells and pumps, however, are capable of again being put to use, if desired.

Effective storage capacity of the ground-water basin in upper San Diego River Valley, from Cape Horn to Old Mission Dam, was estimated by J. C. Kimble, geologist, for studies in connection with Bulletin No. 48, at 24,200 acre-feet. The basin under Mission Valley, between Mission Gorge and Old Town, was estimated to have effective storage capacity of 10,500 acre-feet, but was productive of poor quality water. It is apparent that these two underground reservoirs, if properly charged and drained, might be used to augment surface storage and increase safe yield from San Diego River. Such development would involve spreading flood waters to increase percolation into the ground-water basins, and systematic recapture of the waters by pumping. Water loss by evaporation and transpiration would be reduced if ground-water levels were maintained below the root zone.

The Supreme Court of the State of California has confirmed the paramount right of the City of San Diego to all the waters of San Diego River, by virtue of its "pueblo" right, inherited from its Spanish and Mexican founders. An agreement with the La Mesa,

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Lemon Grove and Spring Valley Irrigation District permits the District a total gross annual diversion from the entire San Diego River Basin of not to exceed 10,000 acre-feet on the average, over a ten-year period. This allowance is subject to the City's paramount rights, and includes water conserved by the District in Cuyamaca Reservoir, and water pumped from its El Monte well field in upper San Diego River Valley above Lakeside. Ground waters of this valley are also pumped by the Lakeside Irrigation District, the Riverview Farms and Lakeside Farms mutual water companies, and numerous individuals, to irrigate approximately 4,000 acres above Mission Gorge. Mission Valley lands are likewise irrigated by pumping from the underground basin between the lower end of Mission Gorge and Presidio Hill.

In order to fully convert the ground-water basins in upper San Diego River and Mission valleys to planned conservation storage for the City's own use, it would be essential that pumping of the ground water by overlying landowners be stopped or rigidly controlled. Otherwise, benefits from spreeding of floodwaters would be reaped by the overlying owners, and the City's efforts at recapture would be inefficient. Agricultural returns from these areas, however, are of considerable importance to the economy of the City. Furthermore, the urban development and population presently dependent upon these underground sources for water supply is sufficiently large that the hardships resulting from diversion of the supply to sole use by the City might involve substantial economic adjustment throughout the surrounding area. Therefore, despite its established perpetual right to waters of the underground basins along San Diego River, the City of San Diego has not attempted to prevent reasonable use of this water by overlying landowners, and has counted on these sources only as a limited source of emergency supply.

Colorado River Water

The major addition to the water supply of the City of San Diego was made in December 1947, when Colorado River water was first delivered through the newly constructed San Diego Aqueduct.

All California rights to waters of the Colorado River are predicated upon the apportionment contemplated in the Colorado River Compact of 1922, and in the Boulder Canyon Project Act of 1928. Under the former, which was a Federally approved compact or agreement between the states of the Colorado River Basin, the "Upper Basin", consisting of those parts of the states of Arizona, Colorado, New Mexico, Utah and Wyoming within and from which waters naturally drain into the Colorado River system above Lee Ferry, was apportioned a total of 7,500,000 acre-feet annually for beneficial consumptive use. The "Lower Basin", consisting of those parts of the states of Arizona, California, Nevada, New Mexico and Utah within and from which waters naturally drain into the Colorado River system below Lee Ferry, was apportioned an equal amount, as well as an additional allocation of 1,000,000 acre-feet annually. The Compact was ratified by legislatures of the several states and approved by Congress. Arizona, however, did not ratify the Compact until 1944. In accordance with provisions of the Boulder Canyon Project Act of 1928, which gave congressional approval to the Compact, the State of California in 1929 enacted legislation, the California Limitation Act, to the effect that its aggregate annual consumptive use (diversions less returns to the river) of Colorado River water would not exceed 4,400,000 acre-feet annually, plus not more than one-half of any surplus waters unapportioned by the Compact.

All of the foregoing rights were beclouded by terms of the Mexican Water Treaty, signed on February 3, 1944, between the United States and Mexico. This treaty allocated

to Mexico a guaranteed annual quantity of 1,500,000 acre-feet, and a conditional annual quantity of 200,000 acre-feet from the already apportioned waters of the Colorado River, and imposed an additional burden upon that limited water supply as compared to ultimate demands therefrom.

The status of California and Arizona rights are presently the subject of major controversy between these states. The controversy hinges upon interpretation of the Colorado River Compact, the Boulder Canyon Project Act, the California Limitation Act, and other relevant documents. Attempts are being made to secure congressional authorization for determination thereof by the United States Supreme Court.

As early as April 15, 1926, the City of San Diego had filed for 155 second-feet, or 112,000 acre-feet of Colorado River water annually, a right that was later broadened to apply to both City and County. Under the Seven-Party Water Agreement of 1930, executed on August 18, 1931 by California claimants to Colorado River water, the City and/or County of San Diego were apportioned 112,000 acre-feet annually, with a fifth priority. In 1933 the Secretary of the Interior contracted to provide the City 250,000 acre-feet of storage capacity in Boulder Reservoir, now Lake Mead, and to deliver 112,000 acre-feet of water each year to the City and/or County at a point on the Colorado River above Imperial Dam. A further contract in 1934 authorized diversion from the All American Canal, on the west side of Imperial Valley. Studies were made and plans formulated for pumping from this source up the eastern slope of the Peninsular Range to a $7\frac{1}{2}$-mile tunnel with intake portal at elevation of 2,750 feet, and then dropping the water into the upper reaches of San Diego River. In the meantime, construction of the Colorado River Aqueduct by the Metropolitan Water District of Southern California was under way, a project completed in 1941 at cost of $191,000,000. This line, with ultimate capacity of 1,655 second-feet, diverts at Parker Dam on the Colorado River, and, through approximately 410 miles of canals, pipes and tunnels, including pump lifts, delivers water to member agencies of the District in the Los Angeles metropolitan area. The possibility of tapping this aqueduct for gravity delivery of Colorado River water to the San Diego region was recognized, and studies of such a route were made as alternative to the proposed pump lift from the All American Canal. No decision as to final course of action was made until 1944. At that time the rapidly increasing water demands of San Diego exceeded safe yield from local sources, and deep inroads had been made on reserves of water in storage. After a comprehensive study of water supply in the San Diego region, as related to national defense, the State Council of Defense in 1943 made the following findings:*

"6. Estimated future mean daily demands on the City of San Diego water system, based on a 50 per cent increase in use in five years including a supply of 3 m.g.d. to the Coronado District system of the California Water and Telephone Company, are 44.0 m.g.d. in 1943, 48.0 m.g.d. in 1944, 50.0 m.g.d. in 1945, 52.0 m.g.d. in 1946 and 53.0 m.g.d. in 1947 ....

"7. With the foregoing estimated demands for water from the City of San Diego water system based on a 50 per cent increase in use in 5 years, including 3 m.g.d. for the Coronado District system, runoff conditions obtaining in a critical period like that of 1895 to 1904, and adequate transmission capacity provided from all of the storage reservoirs to the city distribution system, the entire water supply available to the city from surface storage, except Hodges Reservoir, will be exhausted in April, 1947 ...."

* * *

"9. As the City of San Diego is now heavily overdrawing the safe yield of its water supply, a supplemental water supply must be obtained.

*"Report on Municipal Water Systems-Report No. 3, San Diego Region", Committee on Transportation, Housing, Works and Facilities, State Council of Defense, April 1943.

"The construction of additional storage on local streams will not insure additional safe yield to the City of San Diego and vicinity should dry seasons occur in the immediate future. For example, had San Vicente Reservoir been constructed in 1895 to a capacity of 75,000 acre-feet, and no draft made on it, it would not have filled until 1916.

"Therefore, the supplemental water supply must be obtained from sources outside of the County."

Among the several recommendations of the Council was the following:

"5. Additional Water Supply

(a) Surveys and studies necessary to determine the most feasible route of a transmission line for importation of an additional water supply from the Colorado River, including terminal storage facilities enroute, be initiated immediately, and detailed plans and specifications on the selected route be prepared and construction started in time to reach completion and be in operation before the local supplies are exhausted.

(b) When the most feasible route for a supplemental water supply from the Colorado River has been determined, arrangements be made with the agencies owning existing transmission facilities for the conveyance of such supplemental supply from the Colorado River to the point at which it would be delivered to the new transmission line.

(c) The United States actively assist in making all necessary surveys, studies and negotiations, and in financing the construction of all works required to insure a full and dependable water supply for the City of San Diego, because of the large Federal interests dependent upon this water supply system."

In recognition of urgent need for supplemental water to assure continuation of San Diego's war activities, the President of the United States, on October 3, 1944, appointed an interdepartmental committee to study and recommend methods of constructing and financing facilities for increasing the supply. Following the committee's recommendation the President, on November 29, 1944, approved immediate construction at Government expense of a conduit, now known as the San Diego Aqueduct, to connect with the Colorado River Aqueduct near San Jacinto in Riverside County, and extend to San Vicente Reservoir on the San Diego city system. The United States Bureau of Reclamation prepared final plans, and construction under United States Navy supervision started in 1945. However, with termination of hostilities late in that year, and consequent curtailment of naval activity, notice was given that the project was to be cancelled. After urgent representation by the City and other interested local agencies, a contract was effected in October 1945 between Navy Department and City, whereby the Navy completed construction, and the City agreed to reimburse the Government at the rate of $500,000 per year until the project was paid for, without interest. Legality of this contract was questioned by the Comptroller General in February 1947, but Public Law 482 of the 80th Congress, Chapter 186- 2d Session, approved on April 15, 1948, ratified actions of concerned Federal agencies in constructing the aqueduct, authorized its completion and ratified the Navy's contract with the City. Construction had already continued to completion.

In anticipation of need for an agency with powers to receive, apportion and deliver Colorado River water to cities and public districts within the County, the San Diego County Water Authority was organized on June 9, 1944, under a special enabling act of the California Legislature. Its present membership consists of the cities of Chula Vista, National City, Oceanside and San Diego; the Fallbrook Public Utility District; the Lakeside, San Dieguito and Santa Fe irrigation districts; and the La Mesa, Lemon Grove and Spring Valley Irrigation District. Original membership also included the City of Coronado

and the Ramona Irrigation District, but these agencies withdrew from the Authority in 1946. An agreement between the Authority and the Metropolitan Water District, annexing the Authority to the District, was approved by voters of the Authority's service area in November 1946. It provided for merging of Colorado River water rights of San Diego City and County with those of the District; payment by the Authority of back taxes and interest in the District since formation, over a period of years, without further interest; payment by the District of half the costs of the San Diego Aqueduct, together with assumption of title to its northern portion, and responsibility for enlargement of that portion when required; and for assumption of remaining costs and obligations in the aqueduct by the Authority.

Combined rights of the Metropolitan Water District in the Colorado River total 1,212,000 acre-feet per year, of which 550,000 acre-feet are fourth priority, and the remainder fifth priority, under terms of the Seven-Party Water Agreement of 1930. Based on its assessed valuation, the San Diego County Water Authority was, on June 30, 1946, entitled to about 10.5 per cent of the District's rights, or 128,300 acre-feet per year. The City of San Diego, in turn, was entitled to about 85 per cent of the Authority's rights, amounting to 109,300 acre-feet per year, or nearly 100 million gallons per day. However, the designed capacity of the existing San Diego Aqueduct is only 85 second-feet, or 61,400 acre-feet per year, of which the City's entitlement is approximately 52,200 acre-feet per year, or about 46.6 million gallons per day. Limited experience since opening of the aqueduct indicates actual capacity appreciably in excess of designed.

The San Diego Aqueduct, a gravity-flow conduit 71.1 miles in length, was planned under wartime restrictions as to use of critical materials. While tunnels, and some other structures, were constructed to full capacity of 165 second-feet, the present pipe lines are designed for only 85 second-feet, provision having been made to permit installation of a second identical barrel when such additional capacity is required. The aqueduct intake is at the west portal of San Jacinto Tunnel on the Colorado River Aqueduct. Two miles below the intake an 1,800 acre-foot reservoir regulates flow in the conduit. The line bears southwesterly across Hemet Valley, and then turns southerly, crossing Temecula Creek southeast of Temecula. It crosses San Luis Rey River east of Fallbrook, and San Dieguito River in the upper portion of Lake Hodges, having passed east of Escondido. From Lake Hodges the aqueduct bears southeasterly to San Vicente Reservoir. Seven concrete-lined tunnels, six feet in diameter, have an aggregate length of 4.4 miles. Also included in the work is a total length of 1.75 miles of 48-inch diameter steel pipe. Remainder of the aqueduct consists of reinforced-concrete pipe, ranging in diameter from 96 to 48 inches. Cost of the project is estimated at $14,180,000, of which $12,530,000 is direct construction cost.

Terminus of the aqueduct in San Vicente Reservoir permitted transmission of Colorado River water to the City of San Diego through an existing system, but new feeder lines were required to reach remaining members of the San Diego County Water Authority. With proceeds of a $2,000,000 bond issue, the Authority undertook construction of two such pipe lines, both of which were completed in 1948. One serves the Fallbrook Public Utility District and the City of Oceanside, and the other serves Lakeside Irrigation District, La Mesa, Lemon Grove and Spring Valley Irrigation District, and the cities of National City and Chula Vista. The Santa Fe and San Dieguito irrigation districts, as well as the City of San Diego, are served with Colorado River water by a direct diversion from the aqueduct into Lake Hodges. The City is also constructing additional transmission lines and appurtenances between San Vicente and Murray reservoirs to handle Colorado River water, which facilities were largely completed in 1948.

The San Diego County Water Authority has estimated that combined tax rates under the Metropolitan Water District and the Authority will average $0.55 per $100 of assessed valuation over the 30-year period from 1948 to 1977, inclusive. The levy is comprised of regular taxes by both District and Authority to cover costs of their respective bonded indebtedness, completion and enlargement of system, and operation and maintenance, as well as a special tax by the District to cover payment of back taxes and delinquent interest due from the Authority. It is estimated that the combined rate will have dropped to $0.27 by 1978, and that taxes will be entirely eliminated by 1998. Untreated water delivered through the San Diego Aqueduct is charged for by the District at the rate of $8.00 per acre-foot, while the Authority charges members at the rate of $12.00 per acre-foot.

Transmission and Distribution System

Principal features of the water transmission and distribution system of the City of San Diego are indicated on Plate I. They were described in 1935 in Bulletin No. 48, and in greater detail by the State Council of Defense in its 1943 report. The City maintains three more or less separate and distinct transmission systems from its reservoirs to its service area. These are known as the "Cottonwood-Otay", "San Diego River" and "San Dieguito" systems. The following brief descriptions are based on data obtained from the City of San Diego.

At the upper end of the "Cottonwood-Otay System", water released from Morena Reservoir flows down the channel of Cottonwood Creek to Barrett Reservoir, from whence it passes through Dulzura Conduit for 11 miles, emptying into the channel of Dulzura Creek. Dulzura Conduit, with present capacity of about 29 million gallons per day, consists largely of concrete-lined canal, but contains 4,300 feet of flume and 9,400 feet of tunnel. Dulzura Creek flows into Lower Otay Reservoir. Releases from this reservoir pass through a short tunnel to the Otay Filter Plant, and then enter the 40-inch diameter steel Otay Pipe Line, extending about ten miles to the main city service area, to the northwest. Built for gravity flow, this line since 1945 has been pumped near the filter plant, to increase its capacity from 18 to 27 million gallons per day, and permit more nearly balanced drafts between the Cottonwood-Otay and San Diego River systems. At a distance of $2\frac{1}{2}$ miles from the filter plant the Coronado Pipe Line, a 20-inch diameter, wood-stave pipe serving the Coronado service area of the California Water and Telephone Company, branches from the Otay line.

Under the "San Diego River System", water is transmitted to the city service area from El Capitan and San Vicente reservoirs, and from the new San Diego Aqueduct. Pipe line capacities, as estimated by the City of San Diego for this system, are theoretical maximum figures, under the assumption of full reservoirs. The El Capitan Pipe Line extends about 131,000 feet southwesterly from El Capitan Reservoir to the University Heights Filter Plant in San Diego. The upper section, of 48-inch diameter, welded steel pipe with capacity of 63.4 million gallons per day, is 31,180 feet in length and ends at the El Monte Pumping Plant of the La Mesa, Lemon Grove and Spring Valley Irrigation District, where the District diverts through a 36-inch diameter line of 15 million gallons per day capacity. The middle section is 36-inch diameter, welded steel pipe with capacity of 13.5 million gallons per day, extending 11,560 feet to the City's Lakeside Well Field, while the remainder of the line is 36-inch diameter, lock-bar steel pipe. The

Alvarado Pumping Plant increases terminal capacity of the line from 22.0 to 26.0 million gallons per day, with El Capitan Reservoir full.

The original San Vicente Pipe Line, with capacity of 27.2 million gallons per day, is composed of 42.5-inch diameter, steel cylinder cement-lined pipe, extending 21,780 feet between San Vicente Dam and Lakeside. It connects with the El Capitan line and with the new El Monte Pipe Line, to be described hereafter, thus making it physically possible for exchange of water between El Capitan and San Vicente reservoirs.

In anticipation of delivery of Colorado River water to San Vicente Reservoir, the City voted a $6,000,000 bond issue on April 17, 1945, for construction of pipe lines and appurtenances to handle this supply. This work was largely completed by the end of 1948. A second San Vicente line, with capacity of 37.9 million gallons per day, consisting of 48-inch diameter, reinforced-concrete-cylinder pipe, extends 21,690 feet from the dam to Lakeside, connecting with El Capitan and El Monte transmission lines. Upper section of the El Monte line, from El Monte to Lakeside, consists of 11,300 feet of 48-inch diameter, reinforced-concrete-cylinder pipe with capacity of 34.9 million gallons per day. Remainder of the line consists of 47,110 feet of similar 68-inch diameter pipe and 6,290 feet of 72-inch diameter, concrete-lined pressure tunnel, extending to the Alvarado Treatment Plant adjacent to Murray Reservoir. This new plant will soften Colorado River water and deliver it to Alvarado Reservoir, from whence it will flow to the city mains. The new Alvarado Reservoir has a storage capacity of 20 million gallons, solely for purposes of regulation.

The "San Dieguito System" serves the City's La Jolla service area, and is described in more detail in Chapter VII. In brief, it includes an open concrete-lined conduit, conveying San Dieguito River water from Lake Hodges to San Dieguito Reservoir. From this regulating reservoir a composite pipe line, with terminal capacity of 3.0 million gallons per day, leads southwesterly a distance of 12.4 miles to the Torrey Pines Filtration and Pumping Plant, from whence water is boosted to Torrey Pines Reservoir for regulation. It then flows by gravity through another five miles of pipe to the distribution mains of the La Jolla area.

Service mains within the City's distribution system permit exchange of water between the several principal service areas. Numerous small regulating reservoirs and tanks, with appurtenant booster pumping plants, are designed to service particular areas. Improvement and extension of its distribution system has been a continuing project with the City's Water Department. All water delivered to consumers is chlorinated and the greater part of it is filtered. All services are metered.

Safe Yield

For purposes of this report safe yield is defined as the sustained water supply which would have been available from the source in question without any deficiency during the most severe drought period of record, that from 1895-96 to 1904-05, inclusive. The season utilized in this report is the so-called "irrigation season", from October to September, inclusive, unless otherwise specifically indicated.

TABLE 3

ESTIMATED SAFE YIELD OF PRESENT WATER SUPPLY DEVELOPMENT
OF CITY OF SAN DIEGO

Based on No Deficiency
During Drought Period, 1896-1905, Inclusive

Source	Theoretical		Actual	
	With Reservoirs Filled at Start of Dry Period		Under Present Conditions of Depleted Storage	
	in Acre-Feet per Season	in Million Gallons per Day	in Acre-Feet per Season	in Million Gallons per Day
Local surface streams	35,700	31.9	10,700	9.6
Colorado River	54,800	48.9	54,800	48.9
TOTALS	90,500	80.8	65,500	58.5

Table 3 shows that theoretical safe yield of water, under present development of the San Diego City system, including Colorado River water imported by the San Diego Aqueduct, is 90,500 acre-feet seasonally. However, because of overdraft resultant from wartime expansion, no such amount is actually available to the City at this time. Attainment of full safe yield from local surface streams requires adherence to a rigid schedule of reservoir operation, under which excess waters stored during wet seasons are drawn out and consumed at an annual rate not exceeding the safe yield. This assures that an ensuing dry period is entered with sufficient water in storage to provide the safe yield during each dry season. Because of unprecedented water demands, the City of San Diego has been unable to follow this desirable schedule of reservoir operation during recent years. Fortunately, up to and including the season of 1942-43, the region had enjoyed a seven-year period during which runoff was greatly in excess of normal, and well-filled reservoirs were available to meet wartime requirements. However, since 1943-44, runoff has been deficient, and water consumption has been far greater than safe yield, with the result that at the end of 1948 city reservoirs were less than 25 per cent filled. It follows that safe seasonal yield actually available at this time from local surface streams is not 35,700 acre-feet, but rather a fraction of that amount, estimated as no greater than 30 per cent of theoretical full safe yield, or about 10,700 acre-feet per season.

Because of the pattern of runoff, the City of San Diego cannot in the normal course of events expect to regain full safe yield of its existing local water supply development for a number of years. Dependent entirely upon the vagaries of future weather, the period might be as short as a single season, or as long as fifteen or twenty.

As regards the Colorado River water supply through the San Diego Aqueduct, early reports indicate a capacity of about 16 per cent in excess of design figures. During a season, inevitable shutdowns for maintenance or other causes will reduce this maximum

amount. An arbitrary assumption has therefore been made that overall operating efficiency will be such as to permit average delivery of 105 per cent of designed capacity, and that the City will be entitled to approximately 48.9 million gallons per day, or approximately 54,800 acre-feet per season.

Since no safe yield is contemplated from local ground-water basins, total estimated safe yield available to the City of San Diego at present, with but 25 per cent of its reservoir capacity filled, is about 65,500 acre-feet per season, or 58.5 million gallons per day.

Present Water Utilization

Historical consumption of water in the City of San Diego since 1900 is listed in Table 4, and shown graphically on Plate II, "Water Consumption by City of San Diego". Average per capita consumption during each year for which census figures are available is also shown. It will be noted that forecasts have been advanced for water consumption in 1950 and 1960, which estimates will be discussed in a later section of this chapter.

TABLE 4

WATER CONSUMPTION BY CITY OF SAN DIEGO

Calendar Years

Year	Total Annual		Average per Day		Year	Total Annual		Average per Day	
------	in Million Gallons	in Acre-Feet	in Million Gallons	in Gallons per Capita	------	in Million Gallons	in Acre-Feet	in Million Gallons	in Gallons per Capita
1900	758	2,326	2.08	117	1926	5,229	16,047	14.33	
1901	750	2,302	2.06		1927	5,486	16,836	15.03	
1902	761	2,335	2.08		1928	5,771	17,711	15.77	
1903	733	2,250	2.01		1929	6,115	18,766	16.75	
1904	771	2,366	2.11		1930	5,714	17,536	15.66	106
1905	761	2,335	2.08		1931	5,804	17,812	15.90	
1906	944	2,897	2.59		1932	5,513	16,919	15.06	
1907	1,222	3,750	3.35		1933	5,536	16,989	15.17	
1908	1,386	4,253	3.79		1934	5,946	18,248	16.29	
1909	1,413	4,336	3.87		1935	6,369	19,546	17.45	
1910	1,653	5,073	4.53	114	1936	6,496	19,936	17.75	
1911	1,821	5,588	4.99		1937	7,011	21,516	19.21	
1912	2,095	6,429	5.72		1938	7,339	22,523	20.11	
1913	2,504	7,685	6.86		1939	7,573	23,241	20.75	
1914	2,641	8,105	7.24		1940	8,644	26,528	23.62	116
1915	2,768	8,495	7.58		1941	9,567	29,360	26.21	
1916	2,958	9,078	8.08		1942	13,228	40,595	36.24	
1917	3,151	9,670	8.63		1943	15,401	47,264	42.19	
1918	3,623	11,119	9.93		1944	16,579	50,879	45.30	
1919	3,318	10,183	9.09		1945	18,309	56,188	50.16	
1920	3,560	10,925	9.73	131	1946	16,950	52,018	46.44	128
1921	3,591	11,020	9.84		1947	16,393	50,308	44.91	
1922	3,662	11,238	10.03						
1923	4,340	13,319	11.89				Forecast		
1924	4,482	13,755	12.25		1950	18,200	56,000	50.0	125
1925	4,670	14,332	12.80		1960	22,800	70,000	62.5	125

Most striking feature of past water utilization in the City of San Diego is
the increase during the period of World War II, when consumption jumped from 20.75 mil-
lion gallons per day in 1939 to 50.16 million gallons per day in 1945, an increase of
almost 2.5 times in six years. During both 1946 and 1947 substantial declines from the
1945 peak have been experienced. However, there is indication that the decline is level-
ing off, and that the 1947 figure of 50,300 acre-feet per year, or 44.91 million gallons
per day, approximately represents average utilization under present conditions.

Future Water Requirements

It is readily apparent that an attempt to forecast future water demands of a
city such as San Diego, with its history of rapid normal growth broken by a spasmodic
wartime expansion, is inherently subject to wide possible error. Extraordinary wartime
requirements connected with the Army and Navy are largely unrelated to dominant peacetime
uses, so that there is no firm base for projecting past requirements into the future. In
order to facilitate orderly, long-range planning, however, and to permit timely construc-
tion of works necessary to prevent possible disastrous water shortages, some idea of the
magnitude of probable future demands is necessary. To this end only, and with no pre-
tense of accurate foresight, expected population growth and resultant water requirements
of the City of San Diego up to the year 1960 have been evaluated. In that actual growth
may prove to be greater than indicated by the present forecast, planning should include as
large a factor of safety as is consistent with economic feasibility.

Population

Growth of population within the City of San Diego has been rapid and consistent
each decade since the turn of the century. Between the 1930 and 1940 counts by the United
States Bureau of the Census, population increased from 147,995 to 203,341. This was fol-
lowed by the accelerated expansion of World War II, accompanied unfortunately by a dearth
of reliable data as to population. There is evidence that growth of the City was accel-
erated as far back as 1939, coincident with inauguration of the defense program, but the
major influx occurred in 1942 and 1943, and peak population was probably reached shortly
after termination of World War II hostilities late in 1945. While several agencies made
estimates of population for one or another of the war years, the problem was so complicat-
ed by large increments of transitory military personnel and dependents, and migratory
civilian workers, that the estimates were necessarily crude, and in some cases inconsis-
tent.

At the instigation of communities concerned, the Bureau of the Census commenced
special population counts throughout San Diego County in June 1944, completing the last in
June 1946. These data, shown in Table 5 (page 44), are reliable as of the date of census,
but a period of two years elapsed between first and last counts involving smaller cities.
These years included a rise to an undetermined peak population and a subsequent decline,
so that validity of the county total may be questioned. However, approximately 87 per
cent of the population was counted in the first half of 1946. Only two per cent was count-
ed in 1944, while the remaining population was counted in the early summer of 1945, before
the probable peak figure had been reached. In the aggregate, therefore, as regards the
County as a whole, the special census data are believed fairly representative of conditions
as of early 1946. In a letter reproduced in Appendix G, "Data Regarding Special Census",
the United States Department of Commerce states that military personnel stationed in the
area were included in the census totals.

PLATE II
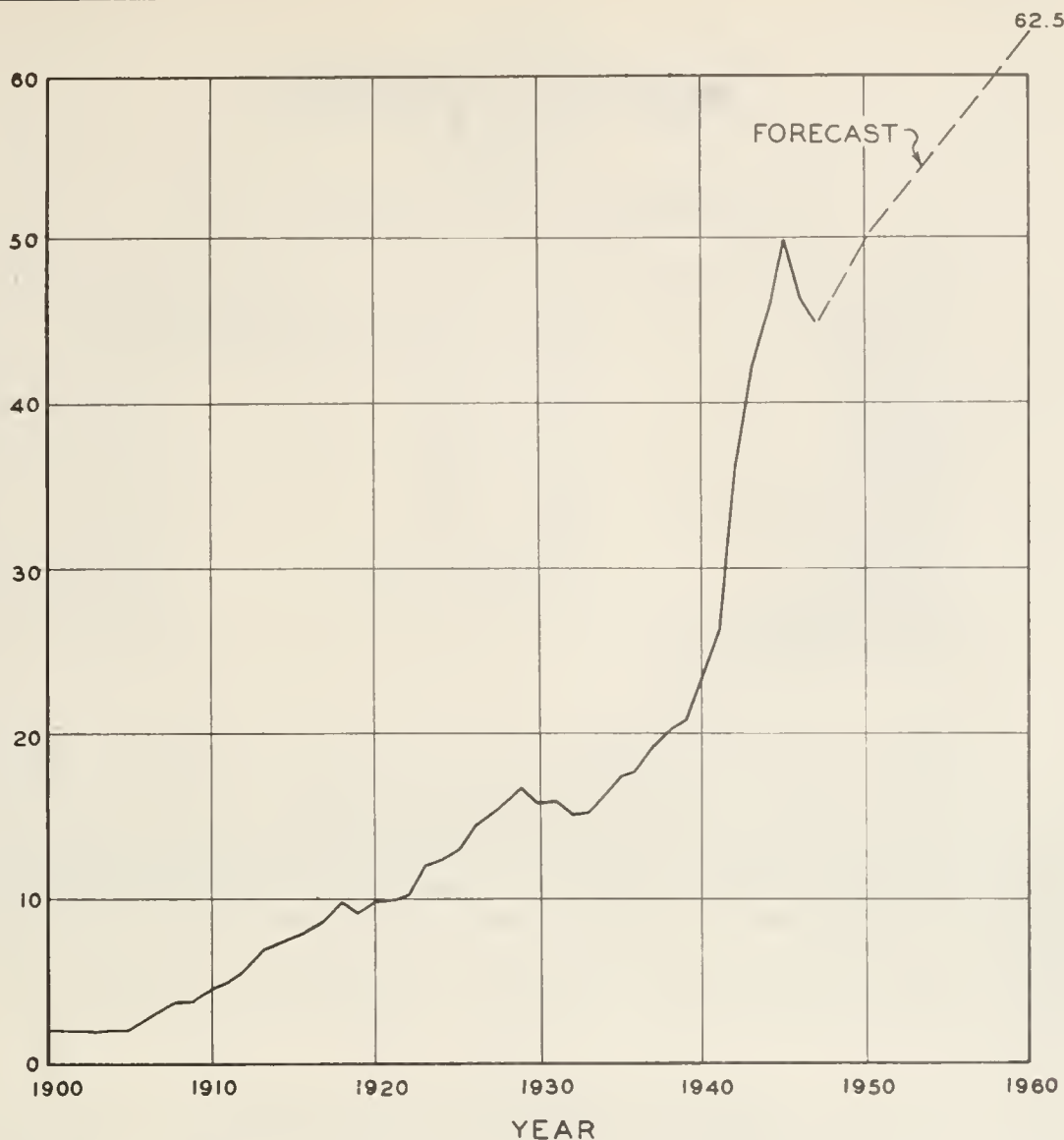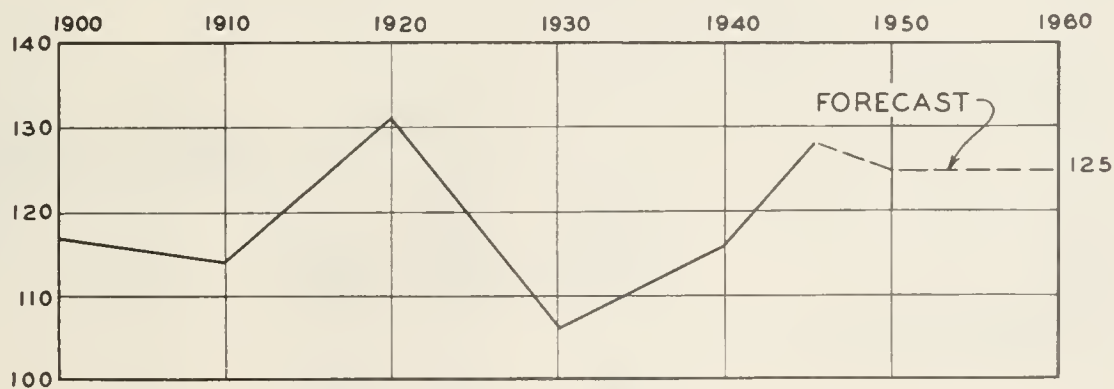
WATER CONSUMPTION
BY
CITY OF SAN DIEGO

TABLE 5

SPECIAL CENSUS OF SAN DIEGO COUNTY
BY UNITED STATES BUREAU OF THE CENSUS

1944-1946

Including Military Personnel Stationed in Area

City or Area	Date of Census	Population
Chula Vista	June 6, 1944	11,081
Coronado	June 5, 1945	25,382
El Cajon	May 8, 1945	3,175
Escondido	June 3, 1946	5,930
La Mesa	May 4, 1945	6,486
National City	May 22, 1945	17,654
Oceanside	June 11, 1945	10,698
San Diego	February 21, 1946	362,658
Unincorporated	April 17, 1946	109,740
TOTAL COUNTY POPULATION		552,804

United States census totals for the County and City of San Diego, beginning in 1860, are listed in Table 6, and shown graphically on Plate III, "Population, County and City of San Diego", as are estimated 1948 population figures, and forecasts for 1950 and 1960. It may be noted that the proportion of total county population residing within the City increased each decade from 1880 to 1930, reaching a peak of 70.6 per cent in the latter year. A slight decline occurred in 1940, and a dropping off to 65.6 per cent for the special census of 1946. It is reasonable to assume that the indicated trend of growth, now favoring rural areas, will continue in San Diego County in the future.

TABLE 6

POPULATION OF COUNTY AND CITY OF SAN DIEGO

Including Military Personnel Stationed in Area

	Year	Population		Per cent of County Population in City
		County	City	
United States census data	1860	4,324	731	16.9
	1870	4,951	2,300	46.5
	1880	8,618	2,637	30.6
	1890	34,987	16,159	46.2
	1900	35,090	17,700	50.4
	1910	61,665	39,578	64.2
	1920	112,248	74,361	66.2
	1930	209,659	147,995	70.6
	1940	289,348	203,341	70.3
	1946	552,804	362,658	65.6
Estimated or forecast by State Division of Water Resources	1948	575,000	375,000	65.4
	1950	615,000	400,000	65.0
	1960	780,000	500,000	64.0

PLATE III
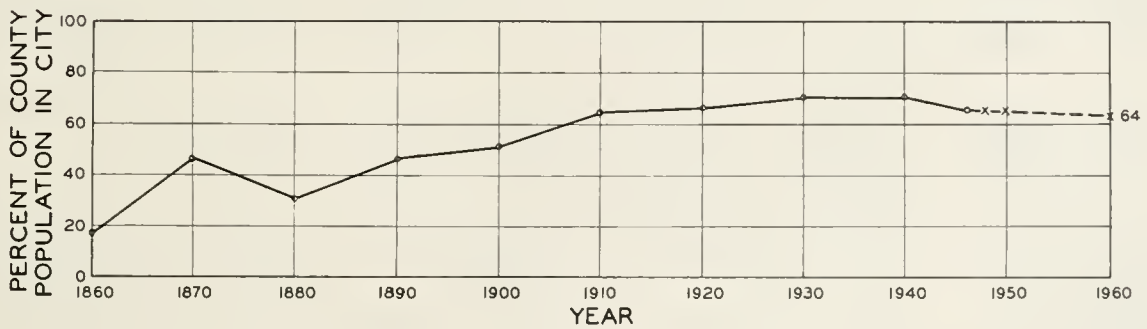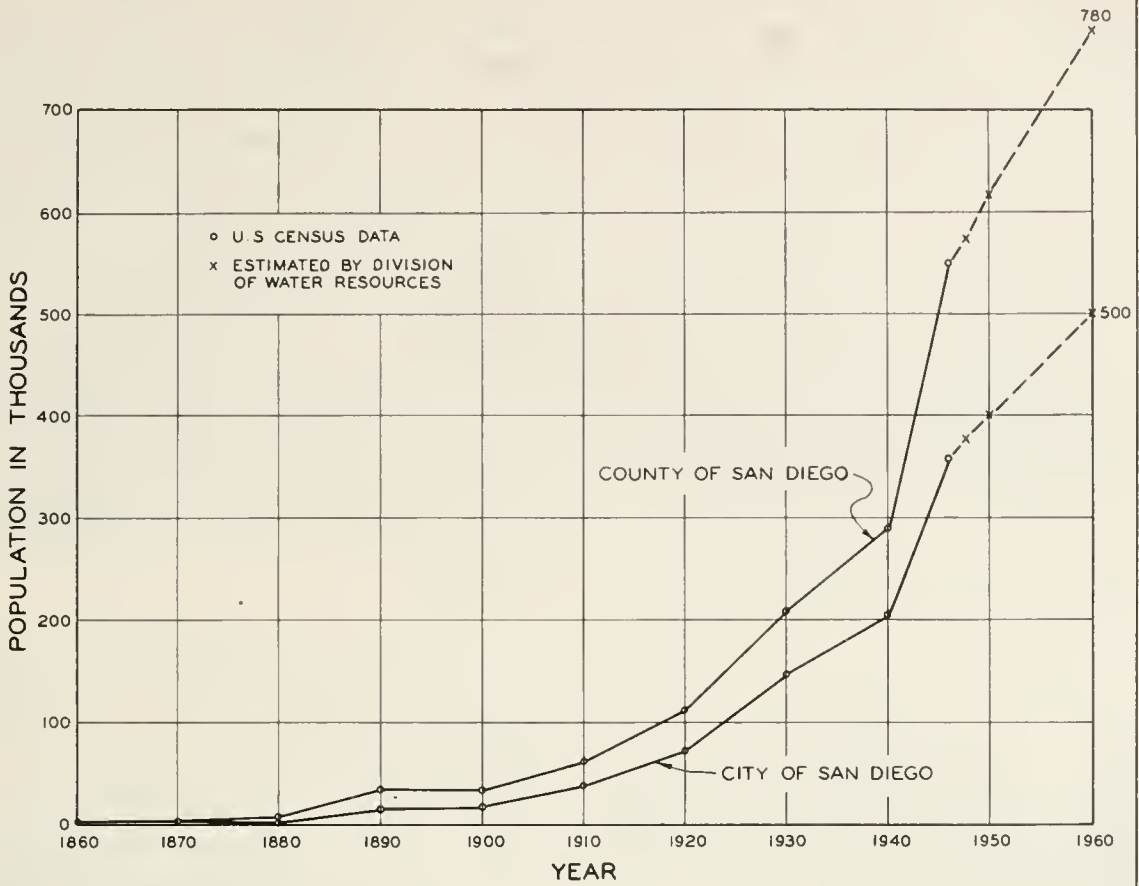
POPULATION
COUNTY AND CITY OF SAN DIEGO
INCLUDING MILITARY PERSONNEL STATIONED IN AREA

Forecasts of population for either San Diego City or County have recently
been made by a number of interested agencies. In Table 7 are shown six independent fore-
casts of San Diego city population to the year 1960. With exception of the first listed,
all have been compiled and published by the Research Department of the San Diego City
Schools.* The first listed is based on a forecast for the entire County by the State Of-
fice of Planning and Research, and has been adjusted to the city area by the Division of
Water Resources. In its derivation, a forecast of population for the years 1950 and 1960,
published by the State Reconstruction and Reemployment Commission in 1946**, was revised
by the State Office of Planning and Research as of January 1948, the revision including an
estimate of July 1947 population. The forecast was based on an intensive analysis of pop-
ulation trends and their causes, throughout the Nation and the State, including considera-
tion of birth and death rates, general migratory movements, and the influences of economic
conditions, wartime displacements, climate, etc. The July 1947 population of San Diego
County was estimated by the State Office of Planning and Research at 500,000, while 525,000
was expected to be reached in 1950, and 625,000 in 1960. If, in accordance with the trend
toward relatively more rapid growth in county area than in the City, it be assumed that
65.0 per cent of total county population will reside within the present city boundaries in
1950, and 64.0 per cent in 1960, then the 1950 population of the City of San Diego would
be 341,000, while the forecast for 1960 would be 432,000.

TABLE 7

FORECASTS OF SAN DIEGO CITY POPULATION TO 1960

Agency Making Forecast	Basis	Population		
		1948	1950	1960
State Office of Plan-ning and Research	Trends of migration and natural increase. Basic forecasts for County adjusted to City by State Division of Water Resources.	327,000#	341,000	432,000
San Diego Chamber of Commerce	Projected 1900-40 rate of increase, modified by postwar experience.	381,066	408,000	666,000
Pacific Telephone and Telegraph Company	1948 and 1950 forecasts - present phone service. 1960 forecast - guess.	372,000	401,666	550,000
San Diego Gas and Electric Company	Projected past rate of County increase, modified by assumed wartime gain of 125,000. Logarithmic projection. Basic forecasts for County adjusted to City by San Diego City Schools.	376,200	396,000	627,000
Mr. John Voss	Projected rate of past increase in num-ber of gainfully employed people.	365,000	390,000	490,000
San Diego City Schools	Trends of migration and natural increase.	379,000	403,600	503,600

Note: # - Estimated July 1947 population.

*"Research Project No. 6, Part I, Population Trends in San Diego 1900 Through 1960",
 Department of Research, San Diego City Schools, April 16, 1948.

**"Estimated Range for Population Growth in California to 1960", State Reconstruction
 and Reemployment Commission, November 1946.

Examination of the forecasts listed in Table 7 discloses a general agreement as to present (1948) and 1950 population, with exception of the forecast by the State Office of Planning and Research, which is markedly lower than the other estimates. A wide divergence in the figures for 1960 may be noted, and again the forecast by the State Office of Planning and Research is lowest. In connection with the original forecast by the State Reconstruction and Reemployment Commission, upon which that of the State Office of Planning and Research was based, the following is quoted from the previously mentioned report of the Research Department of the San Diego City Schools:

"The Commission undoubtedly made a very intensive study and was able to draw upon facts and trends which were collected from many sources. Very careful estimates were made of net migration and natural increase and consideration seemed to be given to the fact that the Los Angeles and San Diego areas have experienced much more rapid growth than other areas in the state. However, ... It seems apparent that the Commission did not anticipate the post war holding power of the San Diego area. This is not surprising inasmuch as most people failed to realize that the San Diego population would become stabilized at such a high figure at the end of the war. On the attached graph which compares the various estimates listed in Table I, it seems apparent that the Commission's figures were approximately 50,000 too low in 1946. If this error is taken into consideration the .... estimates made by the Commission appear to be much more reasonable ...."

Analysis of trends of migration and of natural increase is believed to offer the most rational approach to the problem of forecasting population. It is probably more reliable than any method involving projection of past rates of increase. The respective forecasts by the State Office of Planning and Research and the San Diego City Schools should therefore be given more consideration than the several projections by other agencies. As regards rates of increase, these two favored forecasts are in rather close agreement, their differences being largely due to discrepancies in estimates of present population. In this connection, the foregoing quoted criticism concerning the State Office of Planning and Research forecast is believed to be sound. If this forecast be increased by 50,000, totals for the years 1948, 1950 and 1960 are brought into fairly close agreement with figures derived by the Research Department of the San Diego City Schools. With due allowance for inevitable errors in any population forecast for an area of rapid change such as that of San Diego, the forecast by the Research Department of the San Diego City Schools is believed to be reasonable. Accordingly, for purposes of this study, the present (1948) population of the City of San Diego is estimated at approximately 375,000, while forecasts for 1950 and 1960 are 400,000 and 500,000, respectively.

Water Consumption
In the ordinary circumstance, a study of past characteristics regarding water consumption of a metropolitan area affords a reasonably sound basis for predicting future requirements. In the case of the City of San Diego, however, it is indicated that water demands incident to wartime activities caused a considerable departure from previously observed relationships between population and water consumption. This has been illustrated in Table 4, and on Plate II. It may be noted that, whereas average per capita consumption was consistently less than 120 gallons per day through 1940, with a single exception at the time of the 1920 census, in 1946 the average had jumped to 128 gallons per day.

A portion of the 1946 increase in unit consumption of water in the City may well be attributed to deficient precipitation in that year. However, study of fragmentary data available for the war years indicates that per capita consumption of water was high throughout the period, and that the increase was largely caused by the heavier demands of military and naval installations, and of war industries.

In Bulletin No. 48 an amount of 120 gallons per day per capita was assumed as a basis for estimating water requirements in the metropolitan area of San Diego County, while a figure of 125 gallons per day has been used by several public agencies in arriving at similar more recent estimates. In view of probable continued military use at rates in excess of those before the war, and after consideration of relatively high current over-all rates of consumption, it is believed that an average rate of consumption of 125 gallons per day per capita should be used for estimating future requirements. Utilizing the population forecasts heretofore presented, San Diego city water consumption in 1950 would then be at an average rate of 50.0 million gallons per day, or 56,000 acre-feet per year, and in 1960 would be 62.5 million gallons per day, or 70,000 acre-feet per year.

Ultimate Water Requirements

In view of the uncertainty accompanying forecasts of future population of the City of San Diego, as demonstrated by the wide divergence in forecasts for 1960 listed in Table 7, it is desirable that the problem of future water requirements be studied from some other standpoint independent of population. This may be accomplished through consideration of duty of water over the present gross area of the City under expected conditions of ultimate development.

In its Raymond Basin Investigation* the Division of Water Resources in 1943 made an estimate of areas for various classes of culture in the Raymond Basin area, comprising the City of Pasadena and vicinity, under conditions of ultimate development. The estimate was based on an intensive and comprehensive joint survey and study of existing culture by the Division and by the City of Pasadena. Also, estimates of seasonal duty of water were presented for each cultural classification to which water is artificially applied. These estimates were based largely on meter records of sales by the City of Pasadena, and also upon experimental and observed data from other sources. Mean seasonal duty of water over the entire Raymond Basin area averaged 1.29 acre-feet per acre.

In general, the factors pertaining to ultimate cultural classifications and duty of water in the Raymond Basin area are considered applicable within reasonable limits to the gross area of the City of San Diego. However, allowance must be made for certain significant irregularities. Culture within the two areas, although varying in detail, is roughly comparable, and most variations are compensating. In Pasadena a relatively large proportion of the area is given over to estate type of culture. Seasonal duty of water for estates, however, is almost identical with that for class A residential, a more predominant type in the San Diego vicinity. Whereas ultimate area given over to parks in San Diego may be proportionately greater than in Pasadena, duty of water will be relatively less than in the Raymond Basin area where parks are more intensively developed by lawns, trees and shrubs. The City of San Diego has important industrial and military establishments, types of culture almost totally missing in the Raymond Basin. In compensation, San Diego has proportionately a much larger area that will be vacant under ultimate cultural development. Furthermore, its limited water supply and relatively high water rates are not attractive to heavy industrial users of water. Duty of water for industrial purposes under conditions of ultimate development should not be materially different from the average for municipal, domestic and irrigation uses.

*"Report of Referee, City of Pasadena vs. City of Alhambra, et al, No. Pasadena C-1323", Division of Water Resources, Department of Public Works, State of California, Referee, 1943.

It is indicated, however, that a substantial military and naval load on the city water system, not closely related to ordinary civilian area-duty considerations, will continue indefinitely into the future. This load, which amounted to less than ten per cent of total city consumption in 1940, rose to a peak average of 15.4 million gallons per day throughout the calendar year 1945, constituting nearly 31 per cent of the City's demand. During 1946 the military and naval requirements declined to an average of 11.3 million gallons per day. In light of the present trend toward dispersion of military installations and personnel, it is improbable that the heavy concentrations of World War II will be repeated in the San Diego area. However, to be conservative, an allowance of 15.0 million gallons per day has been made for use by the armed forces, over and above requirements indicated by normal duty of water as applied to the gross city area.

As regards average duty of water over the San Diego city area, analysis of the hydrologic factors affecting consumptive use of water leads to the conclusion that a duty of 1.29 acre-feet per acre in the Raymond Basin corresponds to approximately 1.4 acre-feet per acre in San Diego. Pasadena's average seasonal precipitation of about 22 inches is roughly twice that of San Diego, indicating a relatively higher average duty of water in the latter community. However, this difference is in part compensated for by Pasadena's higher mean maximum temperature, averaging as it does some five degrees above that of the San Diego city area. Included in this latter factor, which favors a low duty figure for San Diego, are the effects of high humidity, cooling ocean winds and summer fogs.

Application of the foregoing adjusted figure for duty of 1.4 acre-feet per acre to San Diego's gross area of approximately 61,100 acres results in an estimate of 85,500 acre-feet seasonally, or 76.3 million gallons per day, for ultimate civilian water requirements. To this should be added the estimate of 15.0 million gallons per day for military and naval needs. If a further working allowance of ten per cent be provided as a factor of safety, the City of San Diego, under conditions of ultimate development of its present incorporated area, should have available a firm water supply of approximately 100 million gallons per day, or 112,000 acre-feet seasonally.

Supplementary Water Supply

Under present conditions of depleted reservoir storage the estimated safe yield of the City of San Diego's existing water supply development, including its share of Colorado River water, totals 65,500 acre-feet per season, approximately 4,500 acre-feet less than forecast water consumption for the year 1960. However, it may be reasonably anticipated that by 1960, with the Colorado River supply now at hand, the City will have added to its reserves in storage, and attained added yield from local surface streams, at least sufficient to meet forecast requirements. It is possible that the maximum safe yield with existing facilities, or 90,500 acre-feet seasonally, may be realized. These premises might lead to the assumption that the City need not pursue further development of its water supply, at least until 1960. Such a conclusion, however, is not conservative, nor does it take into account certain practical considerations regarding San Diego's water supply.

Attention has previously been drawn to the divergence in 1960 population forecasts, and the possible wide range of error in the forecast utilized in this study as a basis for estimating 1960 water consumption. While the forecast is believed at this time to give the most probable picture of water demand, its inherent errors prescribe that it be used with an ample margin of safety.

Although it has been shown that the City of San Diego will have an assured seasonal water supply more than 20,000 acre-feet in excess of its probable 1960 requirements, once its existing reservoirs are filled, such is not the case as regards communities in the adjacent metropolitan area. Further growth and development of these communities, upon which the future welfare and prosperity of the City is in large measure dependent, requires that they be furnished an adequate supplementary water supply. It is considered probable that in their quest for water some such areas will eventually be annexed to the City, increasing its over-all requirements.

Even with the occurrence of a season or seasons of plentiful runoff, there is no positive assurance that safe yield of existing conservation reservoirs will be appreciably built up by any given date in the future. Attainment of additional safe yield from the present local development is dependent upon adherence to a prescribed schedule of reservoir operation, with seasonal draft rigidly limited to desired safe yield, and with demands above this amount met from the imported Colorado River supply. Unless the high degree of discipline implicit in such a program is followed, involving as it does the purchase of imported water at times when seemingly ample quantities of "free" local water are available in reserve, these reserves may well be as depleted in the year 1960 as they are today.

Finally, the City of San Diego has a large investment in reservoir and dam sites and in water rights in the San Dieguito River watershed. These investments are secured and validated by a filing on flood waters of San Dieguito River, made by the City on May 26, 1947, Application No. 11658, which filing can only be maintained by a showing of reasonable diligence toward putting the waters to beneficial use. In view of inescapable uncertainties as to future water supply and demand of the City of San Diego, and in the knowledge that ultimate water requirements of the City together with the adjacent dependent metropolitan area will be greater than existing developed supplies, it may be to the best interests of the City that it take steps to maintain its investments and rights in waters of the San Dieguito River.

Several possible sources of supplementary water supply are available. Chapter VII of this report is devoted to studies of amounts and costs of water available under several plans for further development of San Dieguito River. Similarly, Chapter IX considers supplementary water obtainable through further development of San Diego River. The remaining streams of the western slope in San Diego County all present some possibilities for development of additional safe yield of water, as does the Tia Juana River just below the border in Mexico, and particularly its tributary, Cottonwood Creek, which rises in San Diego County north of the border. A further source of supplementary water lies in the importation of an additional Colorado River supply through construction of the proposed second barrel of the San Diego Aqueduct.

In addition to the ordinary legal, engineering and economic factors entering into choice between the several possible sources for development of a supplementary water supply, the element of time should be considered. In the case of enlargement of the San Diego Aqueduct to provide additional Colorado River water, delivery can be effected immediately after the period required for financing, planning and construction. For projects concerned with further conservation of local surface runoff, however, a substantial additional period must be allowed after construction for accumulation of sufficient stored water to provide the required safe yield.

CHAPTER IV

DESCRIPTION OF SAN DIEGUITO BASIN

San Dieguito River, known in its middle and upper reaches as Santa Ysabel Creek, is one of the principal streams of San Diego County. Its source on the southwest face of Volcan Mountain, an arm of the Peninsular Range, lies about ten miles northeast of the geographical center of the County. The stream flows in a general direction trending south of westerly for about 53 miles, and enters the Pacific Ocean a mile north of Del Mar. It drains an area of 347 square miles, varying in width from three to fifteen miles, and approximately 41 miles in length. Drainage area above the old United States Geological Survey gaging station near Del Mar is 327 square miles. The basin lies between the watersheds of San Luis Rey River and Escondido Creek on the north, and San Diego River and Los Penasquitos Creek on the south. Principal geographical and cultural features of the drainage system are shown on Plate IV, "Drainage Basin of San Dieguito River and Water Service Areas of Organized Agencies".

Topography

The Peninsular Range is a broad, irregular mountain chain roughly paralleling the coast, and extending from the San Jacinto and Santa Ana mountains to its north, southeasterly through San Diego County of which it forms the backbone, on into the peninsula of Lower California. Within the County its eastern slopes are steep and broken, descending rapidly in canyons tributary to the desert floor of Imperial Valley in the Great Basin. Its western slopes, however, are largely typified by the area within San Dieguito Basin, where streams drop quickly from isolated mountain peaks into small highland valleys, and then flow on gradually decreasing slopes through a series of narrow canyons and valleys lying between steep foothills. Broad rolling mesas, incised by narrow alluvial valleys, are characteristic of the mid-portion of the Pacific slope, from whence the streams, now confined to narrow gorges, cut through a coastal belt of hills and marine terraces, finally emerging into flat valleys and entering the ocean through shallow estuaries or marshy lagoons.

From Volcan Mountain, where elevations exceed 5,500 feet above sea level, Santa Ysabel Creek descends in a distance of six or seven miles to an elevation of 3,000 feet in the mountain valley of Santa Ysabel. About four miles below this valley, in a narrow canyon reach, Witch Creek joins the main stream, draining an area to the southeast. The partially constructed Sutherland Dam is a further four miles downstream, below a small valley which interrupts the canyon. Streambed elevation at the dam is about 1,900 feet, and the tributary drainage area of 54 square miles averages 3,350 feet in elevation.

Black Canyon, draining a mountainous area to the north, joins Santa Ysabel Creek about two miles below Sutherland Dam. Temescal Creek, which rises on the slopes of Pine and Black mountains, flows directly south through narrow Pamo Valley to join the main stream some three miles below Black Canyon. Santa Ysabel Creek then turns south for a mile through the lower end of Pamo Valley before again entering a confined, westerly bearing canyon. Three sites near the upstream end of this canyon have been considered for

Pamo Dam. Streambed elevation is approximately 850 feet, and the drainage area of 111 square miles, averaging 2,900 feet above sea level, is largely mountainous in character.

Roden Canyon is the next sizable downstream tributary, entering from the north about three miles below Pamo Valley. After a further canyon reach of approximately three miles, Santa Ysabel Creek enters San Pasqual Valley. This valley averages a little more than a half mile in width and is roughly 5½ miles in length, its flat bottom lands lying at elevations from 350 to 460 feet. Guejito Creek, draining mesa lands to the north, joins Santa Ysabel Creek in this reach, as does Santa Maria Creek, a major tributary from the southeast. The latter stream drains the broad and rolling Santa Maria Valley, a mesa-like basin with average elevation around 1,500 feet. Santa Maria Valley is oval in outline, three to four miles in width and eight miles in length, its longer dimension paralleling Santa Ysabel Creek to the north. Tributary to it on the east are the much smaller Santa Teresa and Ballena valleys, at elevations of about 2,300 and 2,500 feet, respectively. From its junction with Santa Maria Creek downstream to the ocean the main stream is generally known as San Dieguito River.

From a narrows at the lower end of San Pasqual Valley the river passes into the smaller Bernardo Valley, and then enters a confined canyon cut westerly through a belt of coastal hills. About nine miles below San Pasqual Valley, at the narrowest point in a rocky gorge, the waters of the stream are impounded by Hodges Dam. Streambed elevation at the dam, a concrete, multiple-arch structure, is 200 feet. The 303 square miles of drainage area average 1,900 feet in elevation, and are about 40 per cent mountainous, 30 per cent foothill and 30 per cent valley in character. Lake Hodges, at spillway elevation of 315 feet, extends about six miles up the canyon and into Bernardo Valley, storing approximately 33,600 acre-feet of water under present conditions of sedimentation.

For the first five miles downstream from Hodges Dam the river continues within its gorge, and then near the junction with La Jolla Valley, which enters from the southeast, the gorge opens into San Dieguito Valley. This flat, coastal valley, about six miles long and averaging less than a mile in width, is bordered by steep hills rising several hundred feet above the valley floor. At its lower end the valley is tidal marsh, and the river enters the Pacific Ocean from a narrow channel cut through sand bars at almost flat gradient.

Geology

Geologic history and characteristics of San Diego County were adequately presented by the United States Geological Survey in 1919.* It was stated that, while earlier geology of the region is obscure, in late Cretaceous or early Tertiary time the area was part of a peneplain, a low-lying body of land so reduced by erosion that comparatively little topographic relief remained. A period of uplift followed, accompanied by faulting and folding, forming high mountains along the eastern border and partially breaking up the peneplain. At that time streams began to carve the present drainage system. Successive periods of depression, elevation or quiescence followed until the present time, which movements, combined with faulting and erosion, account for topography observed today. Remnants of the ancient peneplain may be noted in the characteristic flattened tops of the

*Water-Supply Paper 446, "Geology and Ground Waters of the Western Part of San Diego County, California", United States Geological Survey, 1919.

PLATE IV

DRAINAGE BASIN OF SAN DIEGUITO RIVER
AND
WATER SERVICE AREAS OF ORGANIZED AGENCIES

SCALE OF MILES
0   1   2   3   4   5

PLATE IV

LOCATION MAP
SCALE OF MILES

DRAINAGE BASIN OF SAN DIEGUITO RIVER
AND
WATER SERVICE AREAS OF ORGANIZED AGENCIES

SCALE OF MILES

County's mountain peaks, and in the rolling mesa-like basins, such as Escondido, Guejito and Santa Maria valleys. Cycles of depression and elevation, accompanied by oceanic submergence and emergence in the western portion of the region, have caused the coastal belt of marine terraces, the successive terraces being separated by wave-cut plains formed during quiescent periods. At one time the land was raised as much as 200 feet above present levels, and streams cut deep channels which, during subsequent subsidence, have filled to existing levels of valley floors, forming the valuable ground-water basins found intermittently along stream channels.

The eastern, highland portion of the Pacific drainage area in San Diego County is composed largely of crystalline rocks, mostly granitic in nature, while rocks of the western, coastal section are of sedimentary origin. In San Dieguito Basin the crystalline rocks extend westerly to a line roughly paralleling the coast and about eight miles from it. A belt of porphyritic intrusive rocks several miles in width separates the crystallines from the alternate beds of shale, sandstone and limestone constituting the coastal sediments.

Ground-Water Basins

San Dieguito Valley is underlain with alluvium and beach deposits which form a ground-water basin more or less coinciding with the surface expression of the valley. This underground reservoir has been exploited by pumping for many years, largely from drilled wells in the upper portion of the valley. Wells in the lower valley are reported to have encountered tight formations with relatively small yield, and water of poor quality.

San Pasqual Valley is likewise underlain with deep alluvium, comprising the most important ground-water basin within the San Dieguito watershed, and one that is extensively pumped for irrigation purposes. This underground reservoir is the subject of more detailed discussion in Chapter VII.

The floor of Santa Maria Valley is composed of crystalline rocks, the surface of which, to variable depths averaging about 100 feet, is decomposed into granitic residuum with appreciable capacity for ground-water storage. Dug wells with galleries are frequently employed for extracting water from this formation. In this valley, too, a zone of shallow alluvium follows the course of Santa Maria Creek, but its storage capacity is small. Guejito Valley is similar to Santa Maria Valley as regards underground water conditions, there being some storage capacity in the prevailing decomposed granite.

While the highland areas of San Dieguito Basin contain no individual ground-water sources of note, the fractured or decomposed rocks constituting much of the surface, and intermittent shallow alluvium along stream channels, do in the aggregate have sufficient water storage capacity to influence appreciably the relationship between precipitation and runoff.

Climate

San Dieguito Basin has climatic characteristics similar to those of the remainder of San Diego County. Along the coast the climate is temperate and equable, with small daily or seasonal variation in temperature. Killing frosts are almost unknown, and summer

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Climate

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temperatures rarely exceed 90° F. At Oceanside, 16 miles north of San Dieguito River,
mean annual temperature is 59° F., and the 1946 seasonal range was only 51 degrees, from
a low of 32° F. to a high of 83° F. Back from the coast and at higher elevations the
extremes are greater. Escondido, 15 miles inland and four miles north of Lake Hodges, at
elevation of 750 feet, has a mean annual temperature of 60.8° F., but the range in 1946
was 73 degrees, from 27° F. to 100° F. At Cuyamaca in the San Diego River watershed,
near the crest of the mountains ten miles south of Santa Ysabel, at elevation 4,677 feet,
average yearly temperature is 53.3° F., ranging during 1946 from 17° F. to 95° F., a dif-
ference of 78 degrees. The eastern slope of the mountains has a desert climate, charac-
terized by Borego Valley, 22 miles east of Volcan Mountain at elevation of 550 feet,
where 1946 extremes were 23° F. and 119° F., a range of 96 degrees, and where mean an-
nual temperature is 70.0° F.

Precipitation occurs principally in four months, from December to March, in-
clusive, with practically none between May 31st and October 1st. Some snow falls annual-
ly in the higher mountains, but accounts for less than ten per cent of precipitation even
there, and is almost never experienced in valley areas. Occasional periods of nocturnal
fog occur along the coast in summer. Precipitation increases with elevation and with
distance from the coast as far as the summit of the mountains, but the eastern slopes are
extremely arid. Mean annual precipitation increases from 12.87 inches at Oceanside, to
16.67 inches at Escondido, and to 39.46 inches at Cuyamaca. At Borego Valley only 1.30
inches of rain fell during the season of 1946. Over a period of years, seasons of sub-
normal precipitation are the general rule, interspersed at more or less regular intervals
of five or six years by single seasons of excessive rainfall. During the infrequent wet
seasons, storms of sufficient intensity and duration to cause destructive flood runoff
sometimes occur.

Native Cover
Natural vegetation throughout San Dieguito Basin is generally sparse. However,
along watercourses there are dense stands of willow, alder, cottonwood, sycamore, swamp
cedar and live oak, and heavy underbrush. In open valley areas, with ground water at or
near the surface, there are heavy growths of tules, salt grass, yerba mansa and other
water-loving vegetation. Southern slopes are largely barren except for annual range
grasses. Northern exposures, however, are chaparrel covered to varying degrees, and may
contain scattered single trees or small groves of cedar, oak and live oak. At elevations
over 4,000 feet there are stands of conifers, including pine and fir. Nowhere can the
basin be described as heavily wooded, and from the standpoint of native cover it is pre-
dominantly grass or brush land.

Population
There is relatively little urban development and, except for a small portion of
the City of Escondido, no incorporated municipality within the San Dieguito watershed.
The mountainous region is very sparsely inhabited, containing only isolated ranches,
small settlements at Mesa Grande, Santa Ysabel and Witch Creek, and the Mesa Grande and
Santa Ysabel Indian reservations. Total population of the mountainous area is estimated
at 800. The largest urban center is Ramona in Santa Maria Valley, a community of about
1,400, serving a tributary area of small farms and scattered ranches in Santa Maria, Santa
Teresa and Pamo valleys, with aggregate population of approximately 350. Upper San Pas-
qual Valley contains small farms, but the lower valley is divided into a few large ranch

holdings. Residents number about 300, with perhaps 50 more on upper Guejito and Bach creeks. Highlands near the basin boundary north of Lake Hodges are developed by estates and small farms centered about Escondido. Population in this locality is estimated to be approximately 1,000. Permanent residents of Del Dios, a resort type subdivision given over to small cabins, on the western shore of Lake Hodges, are about 600. The Santa Fe Ranch, north of San Dieguito River and four miles from the coast, contains the highly developed community center of Rancho Santa Fe, and is broken up into estate type homes and small ranches. Its population within San Dieguito Basin is about 300. Farms and homes in San Dieguito Valley, and scattered ranches south of the river and west of Santa Maria Valley add an estimated 600 to the basin population.

Although available census information does not delineate population within boundaries of the San Dieguito watershed, it is believed to total about 5,400 at this time.

Industry and Agriculture

Agriculture is the predominant activity in San Dieguito Basin, and the only industry of importance at present. However, the 22nd Agricultural District property at the lower end of San Dieguito Valley, near Del Mar, is the site of the San Diego County Fair and of horse racing under auspices of the Del Mar Turf Club, drawing a seasonal group of tourists, workers and race followers to that vicinity. Furthermore, the Cleveland National Forest includes large portions of the upper watershed, and is developed with roads, trails and public camp grounds, so that moderate numbers of campers and picnickers are attracted by the scenic and recreational features of the mountain area.

According to a survey made in 1934, results of which were published in Bulletin No. 48, a total of 6,931 acres were irrigated from San Dieguito River at that time. This figure, however, included coastal lands outside the basin boundaries, and did not include a considerable acreage north of Lake Hodges irrigated by waters of San Luis Rey Basin. It is estimated that actual irrigated area within San Dieguito Basin was about 4,500 acres in 1934. The 1940 Federal census found 13,500 irrigated acres within San Dieguito River and Escondido Creek drainage systems in 1939, an increase of 11.4 per cent over comparable 1934 data from Bulletin No. 48. By the same ratio, irrigated acreage within San Dieguito Basin would have increased to approximately 5,000 acres by 1939. From 1940 census information it may be further deduced that there were about 680 irrigated farms, and $1,000,000 invested in irrigation enterprises in San Dieguito Basin in 1939, a farm being defined as a single holding exceeding three acres, or with agricultural returns exceeding $250. Crop surveys conducted by the Division of Water Resources in 1948 show that approximately 7,300 acres are presently irrigated within the San Dieguito watershed, of which about 3,000 acres are served by water imported from the San Luis Rey River.

Principal areas of irrigation lie in and around San Dieguito and San Pasqual valleys, and to a lesser extent in Santa Maria Valley. In the highland valleys of Santa Ysabel, Santa Teresa and Ballena there is little or no irrigation, and stock raising on natural pasture is the principal agricultural pursuit. There is also dry farming of hay and grains, and small acreages produce apples, pears and grapes. Small amounts of irrigated alfalfa, pasture and field crops are produced in upper Pamo Valley, supporting dairy herds. Remainder of this valley is used for grazing and dry farming.

In Santa Maria Valley limited irrigation supplies are drawn from wells. The

Ramona Irrigation District serves the town of Ramona with domestic water, as well as a small irrigated area in the immediate vicinity. Irrigated crops include citrus, avocados, truck, pasture, alfalfa, field crops, grapes, berries and deciduous fruits. Larger acreages are cultivated to grains and hay without irrigation, but the greater part of the land in the valley is in a natural state, utilized only for grazing. Of recent years the raising of poultry, particularly turkeys, has assumed importance.

San Pasqual Valley is irrigated from surface diversions from Santa Ysabel Creek, and from wells. Dairy farming is predominant in this valley, including the raising of alfalfa, pasture, and field crops, grown on the valley floor, and non-irrigated grains and hay on the adjacent rolling slopes. In the upper end of the valley, however, truck and berry farming is carried on, and there are small orchards of citrus and deciduous fruits.

Bernardo Valley supports little agriculture, except in the high slopes near the drainage divide where there are relatively large acreages of citrus and avocado. Range land in large holdings is found in the hills south of Lake Hodges.

The Santa Fe Irrigation District, obtaining its water by diversion from Lake Hodges, serves lands of the Santa Fe Ranch both within and without the basin. The development is estate type, but there is material agricultural endeavor, including culture of citrus and avocado fruits, walnuts, truck and dry farming of grain and hay. The Fairbanks Ranch at the upper end of San Dieguito Valley is a large single holding within the Santa Fe Irrigation District. It obtains its water supply from the District, but has a standby source in wells in the valley floor and a small reservoir to accumulate local runoff. Agricultural development is similar to that of the Santa Fe Ranch. Truck and field crops, alfalfa and berries are also raised in upper San Dieguito Valley, irrigation supplies being pumped from the underground basin, and there is some dairy farming. Lower reaches of the valley are unsuited for agriculture because of tidal marsh, but non-irrigated beans are grown on lower portions of side slopes near the coast.

Transportation

San Dieguito Basin is served by transportation facilities adequate for its present population and development. The Coast Highway, U. S. 101, a modern, four-lane route, connecting San Diego with all points north, crosses San Dieguito River at its mouth. Some 15 miles inland U. S. Route 395 crosses the watershed from north to south, bridging Lake Hodges at Bernardo, and likewise connecting with San Diego, and by way of Escondido with northern points. A secondary road, State Route 78, extends from Escondido to the east, serving San Pasqual, Santa Maria, Santa Teresa, Ballena and Santa Ysabel valleys. State Route 79 joins Route 78 at Santa Ysabel, and is another through highway from north to south. In addition to these principal roads, a network of county and United States Forest Service roads serves outlying areas within the basin.

Main line rail service is provided along the coast by the Atchison, Topeka and Santa Fe Railway. A branch line from Oceanside through Vista terminates at Escondido, adjacent to San Dieguito Basin on the north, and about 15 miles from the coast.

CHAPTER V

WATER SUPPLY OF SAN DIEGUITO BASIN

Precipitation

Storm Types and Occurrence

The most influential factors determining general occurrence of precipitation in Southern California are the characteristic presence and seasonal displacement of semi-permanent pressure areas over the North Pacific Ocean, which areas develop from general circulation of the earth's atmosphere. To a lesser degree, continental pressure areas also have effect, particularly in the southeastern, Great Basin portion of the State. Local variations in occurrence of precipitation are largely dependent upon topography.

The "Pacific" or "Hawaiian" high pressure area is an anticyclone with center generally in the region between 140°-150° west longitude and 30°-40° north latitude. In strength and area it is greatest in late summer, when its center displaces farthest to the northeast. In January it is at a minimum, with center farthest southeast. The "Aleutian" low pressure area is cyclonic in nature, and develops in the Gulf of Alaska near the Aleutians, or westward toward the Asiatic coast. Since it is caused by the flow of cold polar air from the interior of Asia, it attains greatest extent and intensity in midwinter, at which time its center displaces farthest south. In summer it migrates north, and diminishes to the point where it ceases to affect California weather. Of semi-permanent continental pressure areas, the "North American High Level Anticyclone", a high pressure area forming during the summer in the upper air over New Mexico and Texas, occasionally influences precipitation in San Diego County during that season.

Four general storm types are experienced in the San Diego region.* Of these, the one designated "North Pacific", from the region of its origin, is the most important and dependable, bringing on the average about 43 per cent of the total precipitation, largely during December, January and February. North Pacific storms consist of successive, wave-like masses of polar air, moving in a generally southeasterly and then easterly direction. During winter, waters of the ocean are warm relative to the polar air, and the air masses in their passage absorb moisture and heat to high altitudes, although remaining cold and dry in their uppermost strata. When they reach the North American coast the air masses are therefore unstable convectively, and so laden with water vapor that, upon being lifted in crossing the continental topography, precipitation results. Centers of these storm most frequently approach the coast north of San Francisco, in which cases only gentle rainfall usually falls in the San Diego area. However, if the oceanic pressure areas displace southward, the storm center may pass inland directly across Southern California, and bring intense precipitation to San Diego watersheds.

"South Pacific" storms consist of masses of tropical air originating at 20° to 30° north latitude, on the southwestern side of the Pacific high, around the center of which they move in a generally northeasterly and easterly direction. They do not affect

* "Storm Types and Resultant Precipitation in the San Diego, California, Area", Dean Blake, Monthly Weather Review, Volume 61, August 1933.

California weather when the high is in its usual position. However, under certain circumstances a mass of moist, warm air from this source may pass inland over Southern California. Such storm move rapidly, travel singly, are irregular in occurrence, and vary widely in production from year to year. They may result in very heavy rainfall, and bring on the average about 19 per cent of San Diego County's total seasonal precipitation. South Pacific storms occur principally in February but may appear from November through March.

A third storm type, designated "Interior", produces an average of about 30 per cent of total precipitation in the San Diego area. Often during the passage of storms eastward across the northern border states, or through the Canadian provinces, waves or secondary storms form in the Great Basin, bringing into San Diego County warm, moist air from the southwest. Such storms may occur in any month, but are most frequent from February through May. Their paths are erratic, and their occurrence is unusually unpredictable.

The final storm type in the San Diego area is the "Mexican" or "Sonora" thunderstorm of summer and fall. Travelling northward along the western perimeter of the North American High-Level Anticyclone, masses of warm, moist air from ocean areas on either side of Mexico or Central America may overrun a cooler air mass or become cooled in passage, with resultant convective instability. Ensuing summer precipitation is extremely important over the mountains of Arizona and other southwestern states, and occasionally produces violent cloudbursts over the higher elevations of San Diego County. Sonora storms, however, are responsible for only eight per cent of the County's total precipitation.

Precipitation Stations and Records

Until the recent advent of Colorado River water to San Diego County, local precipitation has been its sole source of water supply. It follows that precipitation has been a matter of great local interest and concern, a fact accounting for the large number of rainfall measuring stations which have been established throughout the region. Bulletin No. 48 listed 138 stations at which precipitation records had been maintained for various periods of time. There are at present 41 active stations on the Pacific slope in San Diego County, fairly well spaced with respect to terrain and elevation. Of active stations, 37 have records of 20 years or longer, 20 have records of 40 years or longer and six have records of 50 years or longer. Oldest record is that at San Diego, which started in 1850 and is unbroken to date, although observations have been made at several locations. The Valley Center record started in 1872, but contains a break of eight years. Precipitation during this period has been estimated from its observed relationship with records at three nearby stations. The Escondido record, a consolidation of observations at two stations, started in 1877 and is continuous to date. Of mountain stations, longest record is that of Julian, which started in 1895, with a gap of 12 years at the turn of the century. Precipitation during these years has been estimated by relating it to the record at Valley Center.

In order to study and evaluate precipitation on the San Dieguito watershed, 31 stations were chosen as representative with respect to location and elevation, and after consideration of duration and quality of their records. Fourteen of these stations are within the watershed, and the remaining 17 are adjacent to or near it. Of stations in the watershed area, seven have records of 20 years or more, and the remainder vary from three to 15 years in length. The 31 stations utilized in precipitation studies of San Dieguito Basin, some of which have included observations at several locations in the same vicinity, are shown on Plate V, "Isohyetal Map of San Dieguito Basin in San Diego County", and listed

PLATE V

HENSHAW
RESERVOIR

T.11 S.

33

32

132

Y SABEL IND   RESERVATION

SANTA YSABEL

NO 1

MESA GRANDE

INDIAN   RESERVATION

28

23

30

ND 3

38

VOLCAN MOUNTAIN

30

29

32

28

Creek

Santa Ysabel
Indian Reservation

22

ND 2

26

T.12 S.

Ysabel

24

ERLAND
M SITE

Santa

39

SANTA YSABEL

40

Witch

Creek

41
WITCH CREEK

Creek

JULIAN

R.4 E.

101

N

T.13 S.

RIVER

DIEGO

SAN

R.3 E.

LEGEND

● ACTIVE STREAM GAGING STATION

● INACTIVE STREAM GAGING STATION

○ PRECIPITATION STATION

━━ BOUNDARY OF SAN DIEGUITO RIVER DRAINAGE BASIN

━ ━ BOUNDARY OF SUB-BASIN

━23━ LINES OF EQUAL SEASONAL PRECIPITATION IN INCHES

96

T.14 S.

CAPITAN GRANDE
INDIA RESERVATION

ISOHYETAL MAP OF SAN DIEGUITO BASIN
IN
SAN DIEGO COUNTY

SCALE OF MILES

0   1   2   3   4   5

PLATE V

ISOHYETAL MAP OF SAN DIEGUITO BASIN
IN
SAN DIEGO COUNTY

in Table 8 under index numbers corresponding to those utilized in Bulletin No. 48, together with descriptions of stations and records. Those monthly precipitation records at each of the stations not published by the United States Weather Bureau, or in Bulletin No. 48, are given in Appendix E, "Monthly Precipitation Records at Stations Representative of San Dieguito Basin".

TABLE 8

PRECIPITATION STATIONS IN OR NEAR SAN DIEGUITO BASIN

Index Number Bulletin No. 48	Station	Location (S.B.B.&M.)			Elevation U.S.G.S. Datum in Feet	Period of Record	Years of Record to July 1, 1948	Source of Record
		Section	Township	Range				
23	San Felipe	30	11 S.	4 E.	3,600	1911-1924[a]	13	San Diego County Water Company
28	Matagual	22	11 S.	3 E.	3,200	1911-1916	5	" " " " "
29	Volcan Mountain	2	12 S.	3 E.	4,800	1911-1924	13	" " " " "
30	Santa Ysabel-Warner Divide	33	11 S.	3 E.	3,200	1913-1916	4	" " " " "
32	Damrons	14	11 S.	2 E.	2,725	1911-1922	11	" " " " "
33	Henshaw Dam	10	11 S.	2 E.	2,702	1911-1948	37	San Diego County Water Company and Vista Irrigation District
36	Amago	26	10 S.	1 E.	2,715	1912-1944	32	U. S. Weather Bureau
37	Mesa Grande (Angels)	21	11 S.	2 E.	3,450	1912-1948[a]	37	C. R. Angel and San Diego County Water Company
38	Mesa Grande	3	12 S.	2 E.	3,350	1905-1948[a]	29	U. S. Weather Bureau, E. H. Davis and Claason Ambler
39	Santa Ysabel Ranch	20	12 S.	3 E.	3,000	1900-1916[a]	15	San Diego County Water Company
40	Santa Ysabel Store	21	12 S.	3 E.	2,983	1911-1948	37	San Diego County Water Company and Santa Ysabel Store
41	Witch Creek	31	12 S.	3 E.	2,800	1909-1916	7	San Diego County Water Company
43	Rosa Glen	32	12 S.	2 E.	2,300	1911-1916	5	" " " " "
44	Pamo Camp	23	12 S.	1 E.	975	1914-1923[a]	10	" " " " "
46	Escondido Ditch Head #1	31	10 S.	1 E.	1,755	1895-1909[a]	12	Escondido Mutual Water Company
46A[b]	Escondido Ditch Head #2	5	11 S.	1 E.	1,770	1909-1928[a]	16	" " " " "
46B[b]	Escondido Ditch Head #3	33	10 S.	1 E.	1,850	1929-1948[a]	19	" " " " "
47	Valley Center #1	8	11 S.	1 W.	1,450	1872-1903	31	City of San Diego and S. Y. Antes
48	Valley Center #2	7	11 S.	1 W.	1,470	1912-1924[a]	13	San Diego County Water Company
48A[b]	Valley Center #3	5	11 S.	1 W.	1,550	1924-1946	22	H. W. Lake
49	Wohlford Lake	33	11 S.	1 W.	1,510	1926-1948	22	Escondido Mutual Water Company
50	Rockwood Ranch	35	12 S.	1 W.	430	1893-1915	22	L. D. Rockwood
51	Ramona #1	15	13 S.	1 E.	1,440	1896-1916	20	Verlaque
52	Ramona #2	15	13 S.	1 E.	1,440	1911-1931	20	Sentinel
53	Ramona #3	16	13 S.	1 E.	1,440	1927-1948[a]	12	U. S. Weather Bureau
53A[b]	Ramona #4	15	13 S.	1 E.	1,450	1942-1948	6	U. C. Upjohn
55	Escondido #1	10	12 S.	2 W.	750	1918-1948	30	U. S. Weather Bureau
56	Escondido #2	22	12 S.	2 W.	660	1894-1935	42	" " " "
56	Escondido #3	22	12 S.	2 W.	660	1887-1897	10	Escondido Land & Town Company
57	Twin Oaks	25	11 S.	3 W.	700	1875-1887	12	Major G. F. Merriam
58	Bernardo Bridge	10	13 S.	2 W.	350	1923-1948[a]	24	City of San Diego
60	Hodges Dam	18	13 S.	2 W.	350	1919-1948	30	" " " "
61	San Dieguito Dam	16	13 S.	3 W.	250	1924-1948[a]	24	" " " "
62	Santa Fe Ranch	32	13 S.	3 W.	55	1912-1915	3	M. H. Crawford
63	Poway	14	14 S.	2 W.	460	1878-1909[a]	26	U. S. Weather Bureau
64	Miramar	5	15 S.	2 W.	660	1901-1948[a]	42	G. A. Riley, S. G. Erro and B. E. Hendrix
69	San Diego	11	17 S.	3 W.	87	1850-1948[c]	98	U. S. Weather Bureau
96	Diverting Dam	11	14 S.	2 E.	840	1899-1939	41	La Mesa, Lemon Grove & Spring Valley Irrigation District
101	Julian	6	13 S.	4 E.	4,222	1879-1948[a]	52	U. S. Weather Bureau
132[b]	Holdredge Ranch	22	11 S.	2 E.	3,480	1935-1948	14	F. E. Holdredge

Notes: a - Broken record.
        b - Not listed in Bulletin No. 48.
        c - Compilation of several records by U. S. Weather Bureau.

in Table 8 under index numbers corresponding to those utilized in Bulletin No. 48, together with descriptions of stations and records. Those monthly precipitation records at each of the stations not published by the United States Weather Bureau, or in Bulletin No. 48, are given in Appendix E, "Monthly Precipitation Records at Stations Representative of San Dieguito Basin".

TABLE 8

PRECIPITATION STATIONS IN OR NEAR SAN DIEGUITO BASIN

Index Number Bulletin No. 48	Station	Location (S.B.B.&M.)			Elevation U.S.G.S. Datum in Feet	Period of Record	Years of Record to July 1, 1948	Source of Record
		Section	Township	Range				
23	San Felipe	30	11 S.	4 E.	3,600	1911-1924[a]	13	San Diego County Water Company
28	Mataguel	22	11 S.	3 E.	3,200	1911-1916	5	" " " " "
29	Volcan Mountain	2	12 S.	3 E.	4,800	1911-1924	13	" " " " "
30	Santa Ysabel-Warner Divide	33	11 S.	3 E.	3,200	1913-1916	4	" " " " "
32	Damrons	14	11 S.	2 E.	2,725	1911-1922	11	" " " " "
33	Henshaw Dam	10	11 S.	2 E.	2,702	1911-1948	37	San Diego County Water Company and Vista Irrigation District
36	Amago	26	10 S.	1 E.	2,715	1912-1944	32	U. S. Weather Bureau
37	Mesa Grande (Angels)	21	11 S.	2 E.	3,450	1912-1948[a]	37	C. R. Angel and San Diego County Water Company
38	Mesa Grande	3	12 S.	2 E.	3,350	1905-1948[e]	29	U. S. Weather Bureau, E. H. Davis and Cleason Ambler
39	Santa Ysabel Ranch	20	12 S.	3 E.	3,000	1900-1916[a]	15	San Diego County Water Company
40	Santa Ysabel Store	21	12 S.	3 E.	2,983	1911-1948	37	San Diego County Water Company and Santa Ysabel Store
41	Witch Creek	31	12 S.	3 E.	2,800	1909-1916	7	San Diego County Water Company
43	Rose Glen	32	12 S.	2 E.	2,300	1911-1916	5	" " " " "
44	Pamo Camp	23	12 S.	1 E.	975	1914-1923[e]	10	" " " " "
46	Escondido Ditch Head #1	31	10 S.	1 E.	1,755	1895-1909[a]	12	Escondido Mutual Water Company
46A[b]	Escondido Ditch Head #2	5	11 S.	1 E.	1,770	1909-1928[e]	16	" " " " "
46B[b]	Escondido Ditch Head #3	33	10 S.	1 E.	1,850	1929-1948[a]	19	" " " " "
47	Valley Center #1	8	11 S.	1 W.	1,450	1872-1903	31	City of San Diego and S. Y. Antes
48	Valley Center #2	7	11 S.	1 W.	1,470	1912-1924[a]	13	San Diego County Water Company
48A[b]	Valley Center #3	5	11 S.	1 W.	1,550	1924-1946	22	H. W. Lake
49	Wohlford Lake	33	11 S.	1 W.	1,510	1926-1948	22	Escondido Mutual Water Company
50	Rockwood Ranch	35	12 S.	1 W.	430	1893-1915	22	L. D. Rockwood
51	Ramona #1	15	13 S.	1 E.	1,440	1896-1916	20	Verlaque
52	Ramona #2	15	13 S.	1 E.	1,440	1911-1931	20	Sentinel
53	Ramona #3	16	13 S.	1 E.	1,440	1927-1948[a]	12	U. S. Weather Bureau
53A[b]	Ramona #4	15	13 S.	1 E.	1,450	1942-1948	6	U. C. Upjohn
55	Escondido #1	10	12 S.	2 W.	750	1918-1948	30	U. S. Weather Bureau
56	Escondido #2	22	12 S.	2 W.	660	1894-1935	42	" " " "
56	Escondido #3	22	12 S.	2 W.	660	1887-1897	10	Escondido Land & Town Company
57	Twin Oaks	25	11 S.	3 W.	700	1875-1887	12	Major G. F. Merriam
58	Bernardo Bridge	10	13 S.	2 W.	350	1923-1948[e]	24	City of San Diego
60	Hodges Dam	18	13 S.	2 W.	350	1919-1948	30	" " " "
61	San Dieguito Dam	16	13 S.	3 W.	250	1924-1948[a]	24	" " " "
62	Santa Fe Ranch	32	13 S.	3 W.	55	1912-1915	3	M. H. Crawford
63	Poway	14	14 S.	2 W.	460	1878-1909[a]	26	U. S. Weather Bureau
64	Miramar	5	15 S.	2 W.	660	1901-1948[a]	42	G. A. Riley, S. G. Erro and B. E. Hendrix
69	San Diego	11	17 S.	3 W.	87	1850-1948[c]	98	U. S. Weather Bureau
96	Diverting Dam	11	14 S.	2 E.	840	1899-1939	41	La Mesa, Lemon Grove & Spring Valley Irrigation District
101	Julian	6	13 S.	4 E.	4,222	1879-1948[e]	52	U. S. Weather Bureau
132[b]	Holdredge Ranch	22	11 S.	2 E.	3,480	1935-1948	14	F. E. Holdredge

Notes: e - Broken record.
        b - Not listed in Bulletin No. 48.
        c - Compilation of several records by U. S. Weather Bureau.

The season utilized in this report in connection with precipitation is the so-called "precipitation season", from July to June, inclusive. This corresponds with the practice of the United States Weather Bureau, and is in contrast to general use herein of the "irrigation season", from October to September, inclusive.

Mean Seasonal Precipitation

In order to facilitate analysis of precipitation in San Dieguito Basin, the stations utilized were more or less arbitrarily divided into three precipitation sub-groups, designation of which as valley, foothill and mountain is indicative of general physical characteristics of areas in which they lie. The division was made in such manner that rainfall indices of stations in each sub-group were most nearly comparable, and for any given year approximately equal. Substantially, valley precipitation stations are those within the range of elevation from sea level to 1,000 feet, foothill stations those from 1,000 to 3,000 feet, and mountain stations those above 3,000 feet in elevation. Included with each sub-group is a control station with long, reliable record of precipitation, which was used as a base for completing or extending shorter records. Thus, the valley sub-group was related to Escondido, the foothill sub-group to Valley Center, and the mountain sub-group to Julian.

The term "rainfall index", as used herein, denotes the ratio of depth of rainfall for any season to mean seasonal depth over a long period of years, expressed as a percentage. Therefore, for any chosen period, the sum of indices for any particular station equals 100 times the number of years in the period. If two or more rainfall stations have closely comparable indices for a period of mutual record, and geographical and terrain factors influencing their precipitation are similar, the assumption may reasonably be made that indices for a longer period of record at one station will equal indices for the same period at the stations not having the longer record. Estimated long-time mean seasonal precipitation at a short record station will then be 100 times its total rainfall during its seasons of record, divided by the sum of long-time period rainfall indices for the same seasons. Estimated precipitation during any year of missing record may be derived through multiplication of the long-time mean figure by the rainfall index for the year.

If a true picture is to be obtained, the period used for determination of rainfall indices should be one of nearly normal precipitation, and should be long enough to include most short-term precipitation records. The long record at San Diego, shown graphically on the bar diagram of Plate VI, "Seasonal Precipitation at San Diego, 1850-51 to 1947-48, Inclusive", offers the best opportunity for determination of normal periods. Rainfall indices based on the 95-year period, 1850-51 to 1944-45, inclusive, were computed for this station, and cumulative departures from the mean were plotted against time. The resulting graph, also shown on Plate VI, indicates that the 50-year period, 1891-92 to 1940-41, inclusive, was essentially one of normal precipitation. It was also a period which included those short-term precipitation records of significance to San Dieguito Basin, and was therefore chosen as a base period for further analysis of precipitation. In support of this choice, if records of the control stations, Escondido, Valley Center and Julian, are related to the San Diego record, and their rainfall over the 95-year period estimated, close relationship between 50 and 95-year mean seasonal rainfall at each station is shown. This is illustrated in the following tabulation:

PLATE VI
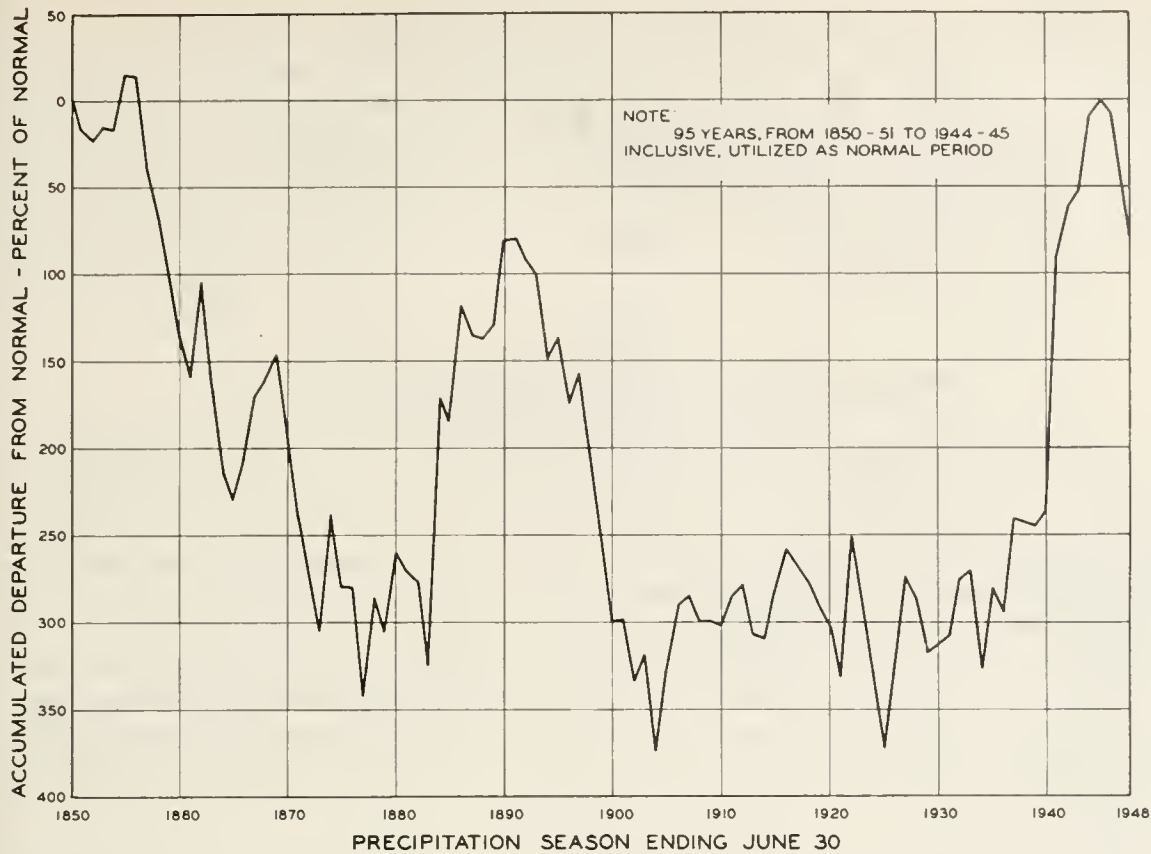
ACCUMULATED DEPARTURE FROM NORMAL PRECIPITATION

DEPTH OF PRECIPITATION
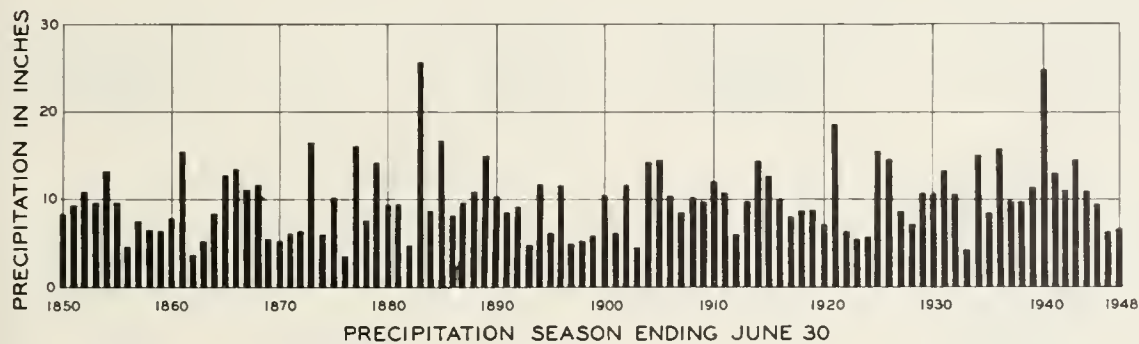
SEASONAL PRECIPITATION AT SAN DIEGO
1850-51 TO 1947-48, INCLUSIVE

Station	Estimated Mean Seasonal Precipitation in Inches	
	95-Year Period, 1850-51 to 1944-45, Inclusive	50-Year period, 1891-92 to 1940-41, Inclusive
San Diego	10.13	10.11
Escondido	16.27	16.64
Valley Center	19.01	19.16
Julian	30.88	31.61
AVERAGE	19.08	19.38

Having chosen a suitable base period, mean seasonal precipitation during that period was estimated for all stations of significance to San Dieguito Basin. From considerations heretofore discussed, each station was assigned to one of the three precipitation sub-groups, valley, foothill or mountain. For each sub-group, those relatively long and reliable precipitation records were related to the record at the concerned control station, and their indices computed for seasons of record. These indices were consolidated, and an average index for the sub-group derived for each season of the base period. Finally, utilizing these average sub-group indices, long-time mean seasonal precipitation at stations with short records was derived. Estimated average seasonal precipitation during the 50-year normal period, 1891-92 to 1940-41, inclusive, at each of the stations utilized in this study, is listed in Table 9.

TABLE 9

ESTIMATED MEAN SEASONAL PRECIPITATION AT STATIONS
IN OR NEAR SAN DIEGUITO BASIN

50-Year Normal Period, 1891-92 to 1940-41, Inclusive

Precipitation Sub-Group	Station	Mean Seasonal Precipitation in Inches of Depth	Precipitation Sub-Group	Station	Mean Seasonal Precipitation in Inches of Depth
Mountain	San Felipe	20.43	Foothill	Escondido Ditch Head	25.32
"	Matagual	21.81	"	Valley Center	19.16
"	Volcan Mountain	31.96	"	Wohlford Lake	19.90
"	Santa Ysabel-Warner Divide	29.94	"	Ramona	18.91
"	Damrons	31.72	"	Twin Oaks	14.96
"	Mesa Grande (Angels)	31.62	Valley	Pamo Camp	18.08
"	Mesa Grande	31.59	"	Rockwood Ranch	14.20
"	Santa Ysabel Ranch	25.77	"	Escondido	16.64
"	Santa Ysabel Store	26.45	"	Bernardo Bridge	15.69
"	Witch Creek	26.40	"	Hodges Dam	15.45
"	Julian	31.61	"	San Dieguito Dam	13.04
"	Holdredge Ranch	32.66	"	Santa Fe Ranch	9.49
Foothill	Henshaw Dam	27.86	"	Poway	16.17
"	Amago	27.44	"	Miramar	13.89
"	Rose Glen	21.96	"	San Diego	10.11
			"	Diverting Dam	16.89

The isohyets, or lines of equal precipitation, of Plate V were drawn up from long-time mean seasonal rainfall values for the stations, due consideration being given terrain factors and the known trend of increase in rainfall with elevation. Average seasonal precipitation over drainage areas above key stream gaging stations in the San Dieguito watershed is given in Table 10, and was derived by planimetering between lines of equal precipitation on the isohyetal map. For the entire San Dieguito drainage area of 347 square miles, seasonal precipitation averaged 19.63 inches in depth, or an amount of 363,300 acre-feet.

TABLE 10

ESTIMATED AVERAGE SEASONAL PRECIPITATION
OVER PRINCIPAL DRAINAGE AREAS
IN SAN DIEGUITO BASIN

50-Year Normal Period, 1891-92 to 1940-41, Inclusive

Gaging Station	Area Above Gaging Station in Square Miles	Average Seasonal Precipitation over Area in Inches
San Dieguito River at Lake Hodges	303	20.89
Guejito Creek near Escondido	28	20.22
Santa Maria Creek near Ramona	60	19.50
Santa Ysabel Creek near Ramona	111	26.26
Santa Ysabel Creek near Mesa Grande	54	28.06

Precipitation Characteristics

Precipitation in San Diego County occurs principally as rainfall, although snow falls in the higher mountains during most seasons. Snows are usually light, aggregating less than ten per cent of total precipitation even at the highest elevations, and melt in a short time, so that their effect on runoff is inconsequential. Nocturnal summer fogs are a material factor in maturing of agricultural crops near the coast, but have no measurable effect on runoff.

In 1919* it was demonstrated that precipitation in western San Diego County increased with altitude from the ocean to the crest of the mountains, the average increase amounting to 0.56 inches of precipitation for each 100-foot rise in elevation. This relationship was generally confirmed in 1935 in Bulletin No. 48. During the present study, mean rainfall of each principal drainage area of San Dieguito Basin was plotted against its mean elevation. A straight line drawn through these points indicated 9.3 inches of precipitation at sea level, and 38.2 inches at 5,000-foot elevation, an average increase of 0.58 inches of rainfall for each 100-foot rise in elevation.

As has been shown in earlier studies, precipitation in San Diego County is marked by wide variation from season to season. Throughout the period of record, maximum seasonal totals have exceeded twice the long-time seasonal average at many stations, whereas minimum seasonal totals are only about half the mean. In many instances, precipitation during the maximum month of record is in excess of the mean seasonal total.

* Water-Supply Paper 446, "Geology and Ground Waters of the Western Part of San Diego County, California", U. S. Geological Survey, 1919.

Monthly distribution of precipitation at San Diego, which is indicative of that throughout the County, is shown in Table 11. San Diego County is characterized by a short, wet, winter season and long, dry summer. In excess of 70 per cent of annual precipitation falls in four months, from December to March, inclusive, and less than ten per cent in five months, from May to September, inclusive. During the present investigation it was determined that for San Dieguito Basin 94 per cent of precipitation fell during seven months, from October to April, inclusive, and that monthly distribution closely followed the relationships established in earlier studies.

TABLE 11

MONTHLY DISTRIBUTION OF PRECIPITATION
AT SAN DIEGO

In Per Cent of Normal Seasonal Total
95-Year Period, 1850-51 to 1944-45, Inclusive

Month	Average During Period	Maximum During Period	Minimum During Period
July	0.5	13.0	0
August	0.9	19.7	0
September	1.1	26.0	0
October	4.7	46.7	0
November	9.1	49.7	0
December	20.6	93.4	0
January	15.7	76.3	0
February	21.0	91.3	0
March	15.7	79.5	0
April	7.1	54.2	0
May	3.0	25.6	0
June	0.6	6.9	0
TOTAL	100.0		

Runoff

Stream Gaging Stations and Records

First recorded stream flow measurements in the San Dieguito watershed were made by the United States Geological Survey in January 1906 at a station on Santa Ysabel Creek in upper San Pasqual Valley ("near Escondido"). Measurements at this location continued until 1912, when a more comprehensive stream gaging program was inaugurated by the Volcan Land and Water Company cooperatively with the same Federal agency. Eight stream gaging stations are presently active on San Dieguito River or its tributaries, and measurements have been made at 16 different sites during various periods subsequent to 1906. Location, drainage area, and duration of record at each of the 16 stations are listed in Table 12, (page 65) under index numbers corresponding to those used in Bulletin No. 48. Locations of the stations are shown on Plate V.

TABLE 12

STREAM GAGING STATIONS IN SAN DIEGUITO BASIN

Index Number Bulletin No. 48	Stream	Station	Location (S.B.B.&M.)			Drainage Area in Square Miles	Period of Record to September 1948	Source of Record
			Section	Township	Range			
22	Santa Ysabel Creek	Near Santa Ysabel	16	12 S.	3 E.	13	Aug. 1913-Sept. 1914	U. S. Geological Survey
23	Santa Ysabel Creek	(At Sutherland)	21	12 S.	2 E.	54	Dec. 1912-Sept. 1928	" " " "
		Near Mesa Grande					Oct. 1928-Sept. 1936	F. E. Green[b]
							Oct. 1936-Sept. 1948	U. S. Geological Survey
24	Black Canyon Creek	Near Mesa Grande	17	12 S.	2 E.	15	Feb. 1913-Sept. 1924	" " " "
25	Temescal Creek	Near Almond	23	12 S.	1 E.	32	Feb. 1913-Nov. 1915	" " " "
26	Santa Ysabel Creek	Near Ramona	27	12 S.	1 E.	111	Feb. 1912-Feb. 1923	" " " "
		(At Pamo)					Oct. 1943-Sept. 1948	" " " "
27	Santa Ysabel Creek	Near Escondido	31	12 S.	1 E.	128	Jan. 1906-Sept. 1912	" " " "
27A[a]	Santa Ysabel Creek	Near San Pasqual	31	12 S.	1 E.	128	Apr. 1947-Sept. 1948	" " " "
28	East San Pasqual Ditch	Near Escondido	36	12 S.	1 W.	-	June 1912-Sept. 1913	" " " "
29	Guejito Creek	Near Escondido	35	12 S	1 W.	28	Feb. 1915-Sept. 1915	" " " "
		(At San Pasqual)					Oct. 1916-Sept. 1917	" " " "
							Oct. 1919-Sept. 1924	F. E. Green[b]
							Oct. 1921-Sept. 1922	Volcan Land & Water Co.
							Oct. 1946-Sept. 1948	U. S. Geological Survey
29A[a]	Guejito Creek	Near San Pasqual	23	12 S.	1 W.	24	Jan. 1947-Sept. 1948	" " " "
30	West San Pasqual Ditch	Near Escondido	34	12 S.	1 W.	-	May 1912-Sept. 1915	" " " "
31	Santa Maria Creek	Near Ramona	11	13 S.	1 W.	60	Oct. 1911-Sept. 1924	F. E. Green[b]
							Nov. 1912-May 1920	U. S. Geological Survey
							Oct. 1919-Sept. 1923	Volcan Land & Water Co.
							Oct. 1946-Sept. 1948	U. S. Geological Survey
32A[a]	San Dieguito River	Near San Pasqual	1	13 S.	2 W.	250	Apr. 1947-Sept. 1948	" " " "
32	San Dieguito River	At Bernardo	11	13 S.	2 W.	270	Apr. 1912-Jan. 1916	" " " "
33	San Dieguito River	At Lake Hodges	18	13 S.	2 W.	303	Jan. 1916-Sept. 1948	" " " "
34	San Dieguito River	Near Del Mar	32	13 S.	3 W.	327	Oct. 1912-Sept. 1914	" " " "

Notes:
a - Not published in Bulletin No. 48
b - Private records of F. E. Green, hydrographer for City of San Diego.

Stream gaging stations at three proposed dam sites are of particular importance to the present investigation. The record for Sutherland dam site, Station No. 23, Santa Ysabel Creek near Mesa Grande, is continuous from December 1912 to date. It is published by the United States Geological Survey, except for the period from October 1928 to September 1936, which is available from the City of San Diego.

For Pamo dam site, Station No. 26, Santa Ysabel Creek near Ramona, the record as published by the United States Geological Survey also starts in 1912 and runs to date, but is broken by a 20-year period of no record, from February 1923 to October 1943. Runoff for the period of missing record was estimated from its relationship with that at Sutherland, established during years of mutual record. Seasonal runoff figures at the two stations were plotted against each other, and a straight line drawn through the points, using the method of least squares. It was thus indicated that Pamo runoff is about 1.60 times that at Sutherland.

Runoff at Hodges Dam, Station No. 33, San Dieguito River at Lake Hodges, is computed by the United States Geological Survey in cooperation with the City of San Diego, and the record is complete from January 1916 to date. The computation involves correction of observed change in storage for release, spill and leakage at the dam, and for evaporation and rainfall on the reservoir surface. For the period from April 1912 to January 1916, runoff at the dam was derived from the record for San Dieguito River at Bernardo by addition of estimated runoff between the two stations.

Monthly runoff at Sutherland, Pamo and Hodges dam sites during the 36-year period of record is given in Appendix F, "Estimated or Measured Actual Monthly Runoff at Key Gaging Stations in San Dieguito Basin, 1912-13 to 1947-48, Inclusive". It should be noted that this tabulation refers to actual runoff at the three stations, rather than full natural runoff. Full natural runoff is that which would occur under natural conditions, unimpaired by upstream diversions, uses and storage development, and without import of water into the basin. In many hydrologic studies full natural flow is evaluated in order to facilitate comparison between runoff of several streams, or different points on the same stream, and was evaluated and so used for San Dieguito River in Bulletin No. 48. In the present investigation, however, it was desired to determine additional yield obtainable by construction of conservation works on San Dieguito River. An evaluation of actual runoff at the several sites was essential for this purpose. In the cases of the Sutherland and Pamo stations, actual and full natural runoff are essentially equal, since only negligible diversions affect the natural regimen of the stream above them. At the Hodges station, however, actual runoff varies from full natural runoff, the difference being due to effects of irrigation diversions and use in San Pasqual Valley. In this connection, it may be observed that for many months, and for some entire seasons, runoff at Hodges is less than at Pamo. This apparent anomaly is explained by losses between the two stations, consisting principally of consumptive use by irrigated crops and native vegetation in San Pasqual Valley, including evaporation from soil and natural water surfaces.

In addition to the above key gaging stations currently maintained in San Dieguito Basin, records are being obtained by the United States Geological Survey at five stations in or adjacent to San Pasqual Valley. These stations were established or re-established cooperatively by the City of San Diego during the present investigation, for the purpose of determining surface inflow and outflow of the valley.

Runoff Under Present Development and Cultural Conditions
Runoff at a given site under present development and cultural conditions represents the amount of water available at the site for further conservation development, without change in the existing regimen of upstream diversion and use. Therefore, in order to determine additional yield obtainable from further conservation works in San Dieguito Basin, actual runoff at the three principal dam sites has been evaluated in this report.

Stream flow measurements in San Dieguito Basin commenced in 1906, and runoff records at Sutherland, Pamo and Hodges dam sites are available only since 1912. However, estimates of runoff during earlier years are desirable for comparative purposes, particularly for those seasons encompassing the extreme ten-year drought from 1895 to 1905.

In order to estimate runoff in the absence of discharge measurements, unsuccessful efforts were made to relate measured precipitation to measured runoff. The results indicated excessive influence by undetermined factors, such as rainfall intensity, storm

frequency, soil conditions, etc. As has been the case in prior investigations, it was concluded that the rainfall-runoff relationship in San Diego County is too erratic to be of value for estimating purposes.

Estimates of seasonal full natural flow at Sutherland and Hodges dam sites were presented in Bulletin No. 48, extending back through the season of 1887-88. For the period from 1906 to 1912 they were based on the record for Santa Ysabel Creek near Escondido. By first multiplying runoff figures at this station by the ratio of its drainage area with that above Pamo dam site, runoff at the latter station was derived. There being no period of mutual record for direct comparison, the assumption that unit area-runoff relationships at the two stations were approximately equal was confirmed by comparison of each with that of the station at Henshaw Dam on San Luis Rey River. Having thus arrived at Pamo runoff for the 1906-1912 period, Sutherland and Hodges seasonal runoff was estimated from relationships with Pamo established during periods of mutual record. For the period 1887 to 1905, estimates of Sutherland and Hodges seasonal runoff were based on their relationship with runoff of San Luis Rey River at Henshaw Dam, established during the period from 1906 to 1933, of which the years from 1913 to 1933 were ones of mutual record. The Henshaw record in its early years was in itself an estimate, being based on runoff of San Luis Rey River near Pala from 1903 to 1911, on runoff of Boulder Creek at Cuyamaca Reservoir, Sweetwater River at Sweetwater Dam and San Jacinto River at Hemet Reservoir from 1895 to 1902, and on runoff of Boulder Creek and Sweetwater River prior to 1895. Since the Bulletin No. 48 estimates involved full natural runoff, that for Hodges dam site included a correction for estimated irrigation diversions and uses in San Pasqual Valley. Measured runoff at Sutherland dam site was assumed equal to full natural runoff, there being only inconsequential use above the station.

Further study during the present investigation disclosed no better methods of estimating runoff in San Dieguito Basin than those utilized for Bulletin No. 48. The unfortunate dearth of early stream flow measurements, and lack of a dependable precipitation-runoff relationship, dictated further use of the roundabout methods of the earlier study. Accordingly, the several relationships between runoff at various stations, as heretofore described, were adjusted to incorporate measured runoff data from 1933 to date. Since present estimates are for actual rather than full natural runoff, correction of the Hodges record for irrigation diversions and uses in San Pasqual Valley was eliminated. Runoff at Pamo dam site during seasons without record was derived from its relationship with Sutherland runoff, as previously discussed, i.e., Pamo runoff equals 1.6 times that at Sutherland. Estimated or measured seasonal runoff at the three key stations in San Dieguito Basin for the 61-year period, 1887-88 to 1947-48, inclusive, are presented in Table 13 (page 68). Runoff at Lake Hodges is shown graphically in the bar diagram of Plate VII, "Estimated or Measured Actual Seasonal Runoff, San Dieguito River at Lake Hodges, 1887-88 to 1947-48, Inclusive". The season referred to in connection with runoff is the one generally utilized throughout this report, the so-called "irrigation season", from October to September, inclusive.

Although the rainfall-runoff relationship in San Dieguito Basin was found to be erratic seasonally, over a period of many years the two should conform closely. Precipitation being the sole source of runoff in the watershed, over a long-time period the several factors affecting the relationship between them should assume average proportions. A period of long-time mean runoff, therefore, should be approximately identical with one of long-time mean precipitation. It has been demonstrated herein that the 50-year period,

TABLE 13

ESTIMATED OR MEASURED ACTUAL SEASONAL RUNOFF
AT KEY GAGING STATIONS
IN SAN DIEGUITO BASIN

in Acre-Feet

Season	At Sutherland Dam Site Station No. 23	At Pamo Dam Site Station No. 26	At Hodges Dam Station No. 33	Season	At Sutherland Dam Site Station No. 23	At Pamo Dam Site Station No. 26	At Hodges Dam Station No. 33
1887-88	8,400	13,400	16,100	1917-18	7,360	12,400	25,600
1888-89	18,900	30,200	43,800	1918-19	4,810	5,870	3,430
1889-90	27,800	44,500	70,400	1919-20	12,500	17,600	14,500
1890-91	25,800	41,300	64,100	1920-21	3,170	4,070	1,490
1891-92	11,700	18,700	24,200	1921-22	47,200	79,700	118,000
1892-93	13,200	21,100	28,100	1922-23	9,560	15,800[c]	16,100
1893-94	4,800	7,680	7,580	1923-24	2,740	4,390	4,750
1894-95	55,300	88,500	163,000	1924-25	3,470	5,550	1,730
1895-96	3,000	4,800	3,650	1925-26	15,300	24,500	34,300
1896-97	9,800	15,700	19,300	1926-27	49,500	79,300	157,000
1897-98	2,200	3,520	1,650	1927-28	3,620	5,800	8,900
1898-99	1,600	2,560	850	1928-29	4,890	7,820	8,500
1899-00	1,500	2,400	460	1929-30	8,010	12,800	15,500
1900-01	6,000	9,600	10,400	1930-31	3,090[a]	4,950	4,810
1901-02	3,800	6,080	5,260	1931-32	31,300[a]	50,000	71,300[d]
1902-03	5,600	8,960	9,300	1932-33	7,600[a]	12,200	17,300
1903-04	2,600	4,160	2,850	1933-34	1,180[a]	1,880	1,550
1904-05	14,900	23,800	32,800	1934-35	4,640[a]	7,420	8,520
1905-06	33,700	54,600	80,100	1935-36	6,330[a]	10,100	11,100
1906-07	19,100	30,900	42,900	1936-37	47,600	76,100	163,000
1907-08	6,000	9,730	9,530	1937-38	29,600	47,400	91,600
1908-09	25,100	40,800	58,500	1938-39	10,800	17,400	40,100
1909-10	18,100	29,400	40,400	1939-40	6,980	11,200	18,100
1910-11	11,900	19,000	24,100	1940-41	43,000	68,800	179,000
1911-12	8,690	14,100	16,400	1941-42	9,120	14,600	39,600
1912-13	4,520[a]	5,780	2,070[b]	1942-43	18,000	28,800[c]	46,700
1913-14	10,500	19,800	21,500[b]	1943-44	12,900	19,400	22,200
1914-15	31,100	49,800	73,600[b]	1944-45	9,630	14,400	17,800
1915-16	95,200	149,000	310,000	1945-46	7,170	10,500	16,400
1916-17	13,700	24,300	32,000	1946-47	2,490	3,710	1,440
MEAN - 50-year normal period, 1891-92 to 1940-41, inclusive:				1947-48	1,200	1,600	- 270[e]
	15,600	25,000	40,700				

Notes: Runoff at all stations for the period 1887-88 to 1911-12, inclusive, and at Pamo dam site for the period 1922-23 to 1942-43, inclusive, estimated by the Division of Water Resources. Remaining values are from records of the United States Geological Survey, except as noted:

a - Observed or estimated by F. E. Green, City of San Diego.
b - Runoff between Bernardo and Hodges dam site estimated by Division of Water Resources, and added to Bernardo runoff.
c - Partly estimated by Division of Water Resources.
d - Corrected by Division of Water Resources for rainfall on the reservoir surface as was done by United States Geological Survey for all other seasons, since construction of Hodges Dam in 1919.
e - Notation by United States Geological Survey: "For months when inflow to the reservoir was small and other elements were large, negative or discordant figures of runoff may appear. To the extent that such discrepancies may be attributed to changes in reservoir capacity since the time of the rating used, or to uncertainties in the rating, quantities too small for periods of falling stage in the reservoir are compensated by quantities too large for periods of corresponding rising stage."

PLATE VII

ACCUMULATED DEPARTURE FROM
NORMAL SEASONAL RUN-OFF
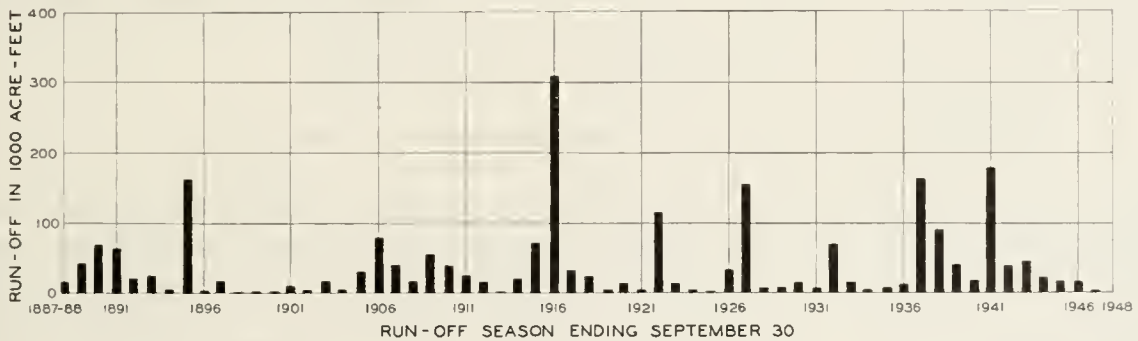
RUN-OFF IN ACRE-FEET

ESTIMATED OR MEASURED ACTUAL SEASONAL RUN-OFF
SAN DIEGUITO RIVER AT LAKE HODGES
1887-88 TO 1947-48, INCLUSIVE

1891-92 to 1940-41, inclusive, was normal as regards precipitation. Assuming this period also to be one of normal runoff, accumulated departure from normal runoff in San Dieguito River at Lake Hodges has been plotted for the 61 seasons of measured or estimated record. This graph is also shown on Plate VII. It will be noted that the normal period embraces two complete and well defined runoff periods or "cycles", each of 25 years' duration, the first from 1891-92 to 1915-16, and the second from 1916-17 to 1940-41, both inclusive.

Comparison of early records of irrigation and other uses of water above Lake Hodges with those of the present day indicates only slight changes since the beginning of runoff measurement. Furthermore, it can be shown that consumptive use of water by native vegetation in San Pasqual Valley is equal to or greater than that by irrigated crops replacing the natural growth. Net effect of past changes in upstream diversions on runoff at Lake Hodges has probably been relatively small. Recorded runoff in San Dieguito River at Lake Hodges throughout the period of measurement is therefore not materially different than it would have been under present development and cultural conditions. Since estimates for prior seasons are based upon runoff during the period of record, they too may be considered as referred to present conditions. With regard to Sutherland and Pamo dam sites, measured runoff is approximately equal to full natural runoff, and no changes of consequence have occurred during the period of runoff measurement. Therefore, seasonal runoff at the three key gaging stations in San Dieguito Basin, throughout the 50-year normal period, 1891-92 to 1940-41, inclusive, as given in Table 13, is essentially the same as under present conditions. Mean seasonal runoff under present development and cultural conditions is estimated at 15,600 acre-feet, 25,000 acre-feet and 40,700 acre-feet for Sutherland, Pamo and Hodges dam sites, respectively.

Runoff Characteristics

Runoff of San Dieguito River and its tributaries is similar in general characteristics to that of other streams of San Diego County. Stream flow is extremely flashy, ranging from very small or zero discharge in summer to torrential floods of destructively high peak flow but short duration, occurring during protracted winter storms. Such floods, which produce the major proportion of total runoff, are experienced only at intervals of five or six years on the average, with the result that runoff for any one year, or even a period of several years, is unpredictable within a wide range.

Examination of the graph of accumulated departure from normal runoff at Lake Hodges on Plate VII discloses that, in addition to apparent complete runoff periods of 25-year duration, shorter periods averaging about five years in length have occurred with marked regularity. Characteristic pattern for these short periods is three or four subnormal seasons followed by a single season of excessive runoff, the flood season mentioned heretofore. Only notable nonconformity as regards occurrence of the five-year period or "cycle" came during the ten-year drought from 1896 to 1905, which was unbroken by an above normal season.

During the 50-year normal period, 1891-92 to 1940-41, inclusive, seasonal runoff in San Dieguito River as measured or estimated has varied from 1.1 to 762 per cent of the seasonal mean. In only 12 seasons was mean runoff exceeded, yet these accounted for approximately 74 per cent of total runoff during the 50-year period. Furthermore, in 28 seasons runoff was less than half the mean, in 19 seasons less than a quarter, and in ten seasons less than ten per cent of the mean. During ten years from 1895-96 to 1904-05, inclusive, runoff averaged about 21 per cent of the long-time seasonal mean. For seven

consecutive seasons during this drought, average runoff was approximately 11 per cent of the 50-year average, while for three consecutive seasons it was only 2.4 per cent. On the other hand, the five seasons from 1936-37 to 1940-41, inclusive, averaged about 240 per cent of normal runoff, and were followed by two substantially normal seasons, beyond limits of the 50-year period.

All but a minor portion of runoff in the San Dieguito watershed occurs during winter and spring, its distribution within each season generally following that of precipitation. There is no appreciable snowpack in the mountains to support stream flow prolonged into summer, and while much of the basin is composed of absorptive materials, with considerable water-storing capacity, drainage from this source does not contribute greatly to summer and fall stream flow. Runoff from granitic residuum of mountains and foothills is rapid immediately following heavy rains, but soon subsides to the point where it is largely consumed by evaporation, and consumptive use of natural vegetation. First rains of fall or early winter are usually absorbed in making up soil moisture deficiencies, or lost to evaporation and consumptive use, and little runoff results. As the rainfall season progresses, storms increase in frequency and intensity, and soil moisture deficiencies are met, with resultant greater runoff relative to precipitation. In an extreme flood year this trend may continue until practically all rainfall goes into immediate surface runoff. This condition was approximated in January 1916, as is indicated in the following tabulation showing relationship between precipitation and resultant runoff, the assumption being made that measured precipitation at a representative location above the gaging station was uniform over the watershed area.

Storm Period, 1915-16	Precipitation at Santa Ysabel Store in Inches	Runoff at Sutherland Dam Site in Per Cent of Precipitation over Drainage Area
Dec. 31 - Jan. 1, inclusive	1.17	1.0
Jan. 4 - Jan. 6, inclusive	0.54	3.7
Jan. 8 - Jan. 10, inclusive	2.11	2.9
Jan. 14 - Jan. 19, inclusive	15.82	50.0
Jan. 24 - Jan. 29, inclusive	10.61	Over 100.0 at this station

Peak runoff month is usually February or March and rarely occurs after March. Stream flow falls off rapidly after final spring rains, and while there is small perennial flow in the mountains, and in valleys where shallow alluvium causes rising water, the contribution to seasonal runoff during summer and fall is very small. Only during extremely wet years does flow in the lower river continue through summer. Average monthly distribution of runoff at Sutherland, Pamo and Hodges dam sites is shown in Table 14 (page 72).

TABLE 14

AVERAGE MONTHLY DISTRIBUTION OF RUNOFF
IN SAN DIEGUITO BASIN

In Per Cent of Seasonal Total

33-Year Period, 1912-13 to 1944-45, Inclusive

Month	At Sutherland Dam Site Station No. 23	At Pamo Dam Site Station No. 26	At Hodges Dam Station No. 33
October	0.5	0.5	0.3
November	0.9	0.9	0.3
December	5.3	5.5	5.5
January	18.0	18.0	22.3
February	26.1	26.8	28.5
March	22.3	22.1	23.1
April	14.6	14.6	12.9
May	7.8	7.5	5.5
June	2.9	2.6	1.3
July	0.9	0.8	0.1
August	0.4	0.4	0.1
September	0.3	0.3	0.1
TOTALS	100.0	100.0	100.0

Import of Water

Up to late in 1948, import of water into the San Dieguito watershed was limited
to that by the Escondido Mutual Water Company, utilized for irrigation of citrus and avo-
cado lands, and minor domestic demands, in an area lying around the rim of the San Die-
guito Basin south of Escondido. However, Lake Hodges lies below the hydraulic grade line
of the San Diego Aqueduct, which crosses above Bernardo, and the reservoir can therefore
be used for regulating a portion of the Colorado River supply. On November 23, 1948,
Colorado River water was first delivered to Lake Hodges from a diversion structure located
on the aqueduct south of the lake. By the end of December in excess of 1,000 acre-feet
had been so diverted for temporary storage and use by the City of San Diego. It is also
planned to use this diversion to serve Colorado River water to the Santa Fe and San Die-
guito irrigation districts. However, service areas of the City, San Dieguito Irrigation
District and a part of the Santa Fe Irrigation District are outside the San Dieguito
watershed, and only that part of the Colorado River supply used by the Santa Fe Irrigation
District on the portion of its service area within the basin boundaries is considered an
import to San Dieguito Basin.

Import from San Luis Rey River

The Soil Conservation Service of the United States Department of Agriculture has
recently made estimates of import of San Luis Rey River water into the San Dieguito

watershed by the Escondido Mutual Water Company.* These estimates, presented in Table 15, are based on meter records.

TABLE 15

ESTIMATED IMPORT OF WATER TO SAN DIEGUITO BASIN
FROM SAN LUIS REY RIVER

By Escondido Mutual Water Company

Season April to March, Inclusive	Import in Acre-feet	Per Cent of Total Water Deliveries By Company
1939-40	1,313	17
1944-45	1,707	22
1945-46	1,984	24

In 1946 the import by Escondido Mutual Water Company was utilized for irrigation of a gross area of 2,550 acres of citrus and avocado groves, and for 280 domestic services in San Dieguito Basin. This constituted 48 per cent of orchard lands under the Company, and 43 per cent of the irrigated acreage. Crop surveys by the Division of Water Resources in 1948 showed that approximately 3,000 acres within the San Dieguito watershed were irrigated by water imported by the Escondido Mutual Water Company. It will be noted that this import is increasing in quantity, as well as in relation to total water deliveries by the Company, and that with maturing of young groves and the present trend toward increased plantings, ultimate import to San Dieguito Basin from the San Luis Rey River may considerably exceed the present figure of about 2,000 acre-feet per season.

In addition to evaluating the foregoing import into San Dieguito Basin, the Soil Conservation Service, in its 1947 report, made estimates of return flow from irrigation as regards this imported supply. For the ten-year period, 1936 to 1945, inclusive, average annual return flow from the entire Escondido Mutual Water Company service area was estimated at 2,300 acre-feet. During the season 1945-46 (April to March, inclusive) 24 per cent of this total amount was estimated to have occurred within San Dieguito Basin, or approximately 550 acre-feet. An undetermined portion of this return flow is known to be intercepted on the surface or pumped from the ground water, and again applied to irrigation or domestic use. A further portion goes into consumptive use of natural vegetation, or evaporation along drainage channels leading toward Lake Hodges. Resultant net accretion to runoff of San Dieguito River as measured at Hodges Dam is believed to be inconsequential.

Import from Colorado River

On the basis of 1946 assessed valuations, and assuming that deliveries in the present San Diego Aqueduct will average 105 per cent of designed capacity, entitlement of the Santa Fe Irrigation District to the Colorado River supply, derived from its membership in the San Diego County Water Authority, is estimated at about 400 acre-feet per season. It is further estimated that the entitlement will increase to about 700 acre-feet when the second barrel of the San Diego Aqueduct is constructed and the full supply is made available

* "The Water Supply of the Escondido Soil Conservation District, San Diego County, California", Soil Conservation Service, U. S. Department of Agriculture, February 1947.

for use. However, it is shown in Chapter VI of this report that average seasonal water utilization by the District under present conditions is approximately 1,000 acre-feet less than its contractual entitlement to San Dieguito Basin water developed at Lake Hodges. Until such time as its water demands increase by 1,000 acre-feet per season, the District may therefore make a choice between use of Colorado River and San Dieguito Basin water, except in times of extreme drought when the local supply may be inadequate.

Average cost to the Santa Fe Irrigation District in 1946 for San Dieguito Basin water purchased from the City of San Diego was $15.15 per acre-foot. The San Diego County Water Authority presently charges $12.00 per acre-foot for Colorado River water delivered to member agencies, in addition to taxes and payments which are independent of water use. It is reported that the City will charge the District $1.50 per acre-foot for transmission and necessary regulation of this foreign water in Lake Hodges and San Dieguito Reservoir, plus a proportionate share of transmission and evaporation losses. The present price differential between San Dieguito and Colorado River water purchases is therefore very small, and the superior quality of the local water may influence its preferred use until such time as increasing demands of the District dictate utilization of the Colorado River supply.

Entitlement of the Santa Fe Irrigation District in the San Diego County Water Authority's Colorado River supply is proportional to respective assessed valuations of the two agencies. Similar considerations govern the Authority's entitlement as a member of the Metropolitan Water District of Southern California. The relative valuations of these agencies may change materially in the future. However, if it be assumed that the relationship will remain as in 1946, the Santa Fe Irrigation District will be entitled to about 700 acre-feet of Colorado River water per season under conditions of ultimate development. On this assumption, and based upon present proportions of irrigated areas of the District inside and outside the basin, it is estimated that approximately 57 per cent of the entitlement, or about 400 acre-feet per season, will be used within San Dieguito Basin under conditions of ultimate development, and will constitute import of Colorado River water to the basin.

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UTILIZATION OF WATERS OF SAN DIEGUITO BASIN

Of water originating within the San Dieguito watershed, a portion is used lo-
cally for irrigation of agricultural crops, and for minor domestic and municipal require-
ments. A larger portion is exported for irrigation, domestic and municipal uses along the
coast to the north and south of San Dieguito Basin. Some of the water supports the growth
of natural grasses utilized for grazing, but the relatively large remainder is lost to
economic use through consumptive use by other native vegetation, evaporation from reser-
voir surfaces, or outflow to the Pacific Ocean.

Early Use of Water
        First development and use of water supplies in San Diego County was by the
Spanish Mission Fathers, who early in the nineteenth century built masonry diversion dams,
and ditches and conduits for irrigation and domestic purposes. There is no evidence, how-
ever, of such mission activities in San Dieguito Basin, and earliest irrigation there was
probably under the East San Pasqual Ditch, built in 1853, shortly after San Pasqual Valley
was settled. Earliest filings to divert water from Santa Ysabel Creek in this valley are
said to have been made in 1876, in connection with the above ditch. There was probably
only minor irrigation outside of San Pasqual Valley prior to the land boom accompanying
completion of the California Southern Railway (now the Atchison, Topeka and Santa Fe Rail-
way) in 1885. That event precipitated great general interest in lands throughout the
County susceptible of irrigation. The West San Pasqual Ditch was built in 1887. In 1888*
it was reported that a total of about 400 acres was irrigated in the San Dieguito drainage
area, consisting of 100 acres in San Dieguito Valley, 150 to 200 in San Pasqual Valley,
100 in Santa Ysabel Valley, and 20 to 25 along Guejito Creek. Development was confined to
direct diversion from unregulated streams, largely by individual farm ditches. At this
early date a project involving conservation storage at Pamo Valley was under promotion.
The plan, which failed to materialize, contemplated export of water for irrigation on
Linda Vista Mesa, north of San Diego, as well as on lands along the conduit.

        By 1912** some 1,300 acres were irrigated within the watershed, but no regula-
tion or conservation improvements had been achieved. The Volcan Land and Water Company
was planning construction of reservoirs in Pamo and Santa Maria valleys, together with
power development, transmission conduits, and delivery of irrigation water on Linda Vista
Mesa. Principal irrigated area was San Pasqual Valley, where about 1,000 acres of alfalfa,
vegetables and deciduous fruits were under ditches of the East San Pasqual Ditch Company
and West San Pasqual Water Company, unincorporated mutual associations formed many years
earlier. A few wells had been drilled in this valley, and artesian flow was reported. In
San Dieguito Valley 150 acres were under irrigation, with principal crop of alfalfa. Three
wells were drilled there in 1909 by the Del Mar Water, Light and Power Company, for muni-
cipal supply to the town of Del Mar. In the vicinity of Ramona in Santa Maria Valley, 102
acres were reported under irrigation.

*"Irrigation in California, Part II, Southern California", William Ham. Hall, 1888.
**"Report of the Conservation Commission of the State of California", 1912.

San Dieguito System

First, and to this date the only major water supply development in San Dieguito
Basin came with construction of Hodges Dam and related structures, commonly known as the
"San Dieguito System", completed by the San Dieguito Mutual Water Company in 1919. Owner-
ship of the system, comprised of Hodges and San Dieguito dams, reservoir lands and water
rights; Pamo and Sutherland reservoir lands; Hodges Conduit, between Hodges and San Die-
guito reservoirs; the "Joint Gravity" and "Lockwood Mesa-Torrey Pines" pipe lines to the
San Diego city limits; and a regulating reservoir below San Dieguito Dam, was transferred
from the San Dieguito Mutual Water Company to its successor, the San Dieguito Water Com-
pany, in 1925. On October 5, 1925, the City of San Diego leased the system for a 30-year
period, with option to buy for $3,750,000, subject to option payment of $500,000 before
January 1, 1926. The $500,000 payment, raised by bond issue, was made on December 1, 1925,
on which date the City assumed possession and operation of the system. The lease contract
provided for monthly payments, a portion of each payment to be applied to the purchase
price, and the remainder to rental. Under the contract the City assumed responsibility
for commitments of the Company to sell specified annual amounts of water to the Santa Fe
and San Dieguito irrigation districts and the Del Mar Water, Light and Power Company.
These three agencies are commonly termed the "Committees". Ownership of the San Dieguito
System was acquired by the City of San Diego in 1939, through payment of the remainder due
under the 1925 contract to the San Diego Water Supply Company, successor in interest to
the San Dieguito Water Company.

Water Service Agencies

Three irrigation districts, one private corporation, and the City of San Diego
comprise the principal water service agencies utilizing water from San Dieguito Basin.
Boundaries of the City are delineated on Plate I, while service areas of the remaining
organized agencies are shown on Plate IV. There are also several loosely organized mutual
water companies, and three Indian reservations within the watershed, but their water re-
quirements are of relatively minor importance, and will be considered generally in a later
section of this chapter.

San Dieguito Irrigation District

This District was organized on March 18, 1922, under the California Irrigation
District Act, to provide irrigation and domestic water to a gross area of about 4,000 acres
along the coast between Batiquitos and San Elijo lagoons. It was consolidated with the
older Cardiff Irrigation District on September 26, 1922. The area, which includes the un-
incorporated communities of Leucadia, Encinitas and Cardiff, is outside the San Dieguito
watershed, so that the District's water supply from Lake Hodges constitutes an export from
San Dieguito Basin.

Under a contract, dated January 18, 1923, the Santa Fe Land Improvement Company
agreed to furnish the District a maximum of 3,200 acre-feet of water during each contract
season from November to October, inclusive, delivery and measurement to be made by the Com-
pany at San Dieguito Reservoir. Rates were $0.03 and $0.075 per 100 cubic feet for irri-
gation and domestic water, respectively, with minimum seasonal charges scaled up to $41,600
after 1928-29. On August 24, 1925, a contract between the San Dieguito Water Company, suc-
cessor in interest to the Santa Fe Land Improvement Company, and the San Diego County Water
Company provided that the latter company furnish supplementary water from San Luis Rey
watershed during drought periods, sufficient to assure the District a seasonal supply of

75 per cent of 3,200 acre-feet, this contract to terminate upon development of additional water supply in San Dieguito Basin by the San Dieguito Water Company.

The City of San Diego having, on October 5, 1925, assumed obligations of the San Dieguito Water Company to supply water to the District, an agreement between District, City and Company was signed on March 12, 1926, perpetuating terms of the original 1923 contract with Santa Fe Land Improvement Company. On April 2, 1935, an agreement between District, City and San Diego Water Supply Company, successor in interest to the San Dieguito Water Company, temporarily released the District from the $41,600 minimum payment, rates at the same time being increased to $0.035 and $0.08 per 100 cubic feet for irrigation and domestic water, respectively. These changes held until back payments due, plus interest, had been paid by the District.

The District, in anticipation of need for water to supplement its entitlement of 3,200 acre-feet annually from the San Dieguito System, employed A. L. Sonderegger, Consulting Engineer, to investigate additional sources. His report of January 1947 considered the relative advantages of developing new storage and yield on San Dieguito River below Hodges Dam, or of obtaining Colorado River water through membership in the San Diego County Water Authority. In August 1946 the District filed an application with the Division of Water Resources for 30,000 acre-feet per annum of flood waters of San Dieguito River at Santa Fe dam site, three miles below Hodges Dam, but this filing was cancelled in September 1947 at the request of the District. Following this, the District applied for entry into the San Diego County Water Authority, and use of its Colorado River supply. The application was approved by the Authority and the Metropolitan Water District, and in November 1948 by the electorate of the San Dieguito Irrigation District.

On the basis of 1946 assessed valuations, entitlement of the San Dieguito Irrigation District to the Colorado River supply is about 500 acre-feet per season, and will increase to about 1,000 acre-feet when the second barrel of the San Diego Aqueduct is constructed and the full supply is made available for use. Up to the end of 1948 the District had received no Colorado River water. The San Diego County Water Authority presently charges $12.00 per acre-foot for Colorado River water delivered to member agencies, in addition to taxes and payments which are independent of water use. It is reported that the City of San Diego will charge the District $1.50 per acre-foot for transmission and necessary regulation of this foreign water in the San Dieguito System, plus a proportionate share of transmission and evaporation losses.

Initial development of the San Dieguito Irrigation District was financed by proceeds of a $400,000 bond issue. A 7½-mile, wood-stave pipe line was built from San Dieguito Reservoir to the District's lands in 1923. This line, consisting of 36,700 feet of 26-inch and 3,630 feet of 24-inch diameter pipe, has present capacity of about seven second-feet. It was extensively repaired with Federal Works Progress Administration assistance in 1938 and 1939, but is still in poor condition and barely adequate for present demands. The District now proposes a $400,000 bond issue to replace this line with a 27-inch main, approximately 40,000 feet in length, made up principally of centrifugally-spun, reinforced-concrete pipe. Capacity would be 14.5 second-feet, sufficient for ultimate expected demands of the District. A complete distribution system serves district lands, including pumps and reservoirs to reach 1,526 acres of high lands above the gravity main, with average lift of about 125 feet. All services are metered, and the water is chlorinated. In 1946 the District constructed a dam and reservoir, Lake Nunn, of 100 acre-foot

capacity, in the hills one mile east of Encinitas. This regulating reservoir floats on the main supply line. Its cost was about $80,000.

Lands of the District are rolling and well drained. Soils, as classified by the United States Department of Agriculture, are deep, medium to fine-grained sandy loams, underlain with moderately compact sandstone. They contain no alkali, are easily worked, and in conjunction with the favorable coastal climate, are suited to production of high return irrigated crops. However, a reduction in irrigated acreage has occurred since 1936. As cultivated areas are subdivided and sold for home sites they are replaced by new plantings, but with some loss in cultivated area. Table 16 shows that irrigated lands decreased 167 acres between 1936 and 1948. In the period 1936 to 1946 irrigation service meters increased from 615 to 991, and domestic meters from 691 to 1,252, indicating reduction in average size of farms, and a trend toward small homesites. Population within the District was 4,375 in 1947, nearly twice the estimated 2,400 in 1936.

TABLE 16

ESTIMATED ACREAGE OF IRRIGATED CROPS
IN SAN DIEGUITO IRRIGATION DISTRICT

Crop	From Annual District Report to California District Securities Commission for 1936	From 1948 Crop Survey by Division of Water Resources
Citrus	8	4
Avocados	1,089	791
Truck	395	461
Flowers	150	186
Miscellaneous	46	79
TOTALS	1,688	1,521

Average cost of water to the District in 1946 was $18.19 per acre-foot, and pumping costs for 535 acre-feet boosted were $6.08 per acre-foot. Consumers paid $0.04 and $0.11 per 100 cubic feet, respectively, for irrigation and domestic water, and $0.01 in addition in the case of boosted water. The district tax levy amounted to $60,303, a $3.00 rate being assessed against 3,520 acres with valuation of $2,010,359.

Financial condition of the San Dieguito Irrigation District has improved, after difficulties during the depression years in the 1930s. At the end of 1946 only $164,000 in bonds were outstanding, the original issue having been refinanced by the Federal Reconstruction Finance Corporation in 1935. District assets totalled $427,227, and capital surplus was $158,150.

Present Water Utilization
As is shown by Table 17 (page 79), purchases of water by the San Dieguito Irrigation District during 1945-46 and 1946-47 averaged 3,270 acre-feet, an amount approximately 1,000 acre-feet greater than the mean for the five preceding seasons. While these recent unprecedented demands reflect in part the growth and development of the District, the marked deficiencies in precipitation during both seasons probably had as great an

influence. It is believed, therefore that present water utilization by San Dieguito Irrigation District averages about 2,810 acre-feet per season, the mean for the five seasons from 1942-43 to 1946-47, inclusive.

TABLE 17

WATER FROM SAN DIEGUITO BASIN
DELIVERED TO SAN DIEGUITO IRRIGATION DISTRICT

Season	In Million Gallons	In Acre-Feet	Season	In Million Gallons	In Acre-Feet
1926-27	418	1,281	1937-38	753	2,310
1927-28	408	1,252	1938-39	778	2,388
1928-29	548	1,682	1939-40	756	2,320
1929-30	636	1,951	1940-41	632	1,940
1930-31	747	2,292	1941-42	643	1,973
1931-32	661	2,030	1942-43	782	2,400
1932-33	651	1,999	1943-44	817	2,506
1933-34	772	2,370	1944-45	856	2,625
1934-35	665	2,040	1945-46	1,030	3,159
1935-36	863	2,648	1946-47	1,103	3,384
1936-37	671	2,060			

It should be noted that deliveries to the District in 1946-47 were in excess of its 3,200 acre-foot entitlement from the San Dieguito System. The excess amount was purchased on short-term contract from the Del Mar Water, Light and Power Company, and was from San Dieguito Basin sources.

Of water received by the District, about 80 per cent is used for irrigation, 15 per cent for domestic purposes, and losses average about five per cent.

Ultimate Water Utilization

While gross area of the San Dieguito Irrigation District is 4,020 acres, only about 3,300 acres are considered suitable for irrigated agriculture or domestic settlement under conditions of ultimate development. The District will probably then be characterized by a mixed culture of suburban homes and small farms and groves, in continuation of the present trend. It is probable that water use will be predominantly for irrigation, as it is at this time. It was found in Bulletin No. 48 that average annual gross allowance of water for irrigation in San Diego County is about 1.3 acre-feet per acre. Application of this duty to the foregoing 3,300 acres of suitable land results in a seasonal water requirement of about 4,300 acre-feet. If a further working allowance of ten per cent be provided as a factor of safety, the San Dieguito Irrigation District, under conditions of ultimate development of its present service area, should have available a firm water supply of approximately 4,800 acre-feet per season.

If it be assumed that the relationship between assessed valuations of the San Dieguito Irrigation District, San Diego County Water Authority and Metropolitan Water District will remain as in 1946, the San Dieguito Irrigation District will eventually receive its entitlement of about 1,000 acre-feet of Colorado River water per season. The District will continue to receive its present seasonal entitlement of 3,200 acre-feet of San Dieguito Basin water. It is considered probable that the District's requirement for supplementary water to meet its ultimate demand, in an estimated amount of 600 acre-feet per season, will be met by water from San Dieguito Basin. This follows from geographical situation of the San Dieguito Irrigation District relative to the Basin and its established use of the water.

Santa Fe Irrigation District

This District was organized on February 26, 1923, under the California Irrigation District Act, and provides irrigation and domestic water to a gross area of about 10,000 acres, most of which lies on the ridge between San Elijo Creek and San Dieguito River. The area, which includes the unincorporated communities of Solana Beach and Rancho Santa Fe, is partly inside and partly outside the San Dieguito watershed. A portion of the District's water supply from Lake Hodges therefore constitutes an export from San Dieguito Basin.

The District initially obtained water under a contract with the Santa Fe Land Improvement Company, dated June 16, 1924. This was superseded on November 1, 1925, when a contract was signed with the San Dieguito Water Company, successor in interest to the Santa Fe Land Improvement Company, providing for a maximum supply of 6,576 acre-feet to the District during each contract season from November to October, inclusive. The Company agreed to deliver and measure the water at a point on Hodges Conduit, at San Dieguito Reservoir, and at Lockwood Mesa near the coast. Prescribed rates were $0.03 and $0.075 per 100 cubic feet for irrigation and domestic water, respectively, with minimum seasonal charges scaled up to $87,935.17 after 1930-31. Also, on November 1, 1925 a contract between District, San Dieguito Water Company and San Diego County Water Company provided that the latter company furnish supplementary water from San Luis Rey watershed during drought periods, sufficient to assure the District a seasonal supply of 75 per cent of 6,576 acre-feet, this contract to terminate upon development of additional water supply in San Dieguito Basin by the San Dieguito Water Company.

The City of San Diego had already, on October 5, 1925, agreed to assume obligations of the San Dieguito Water Company to the District. An agreement between District and City, on September 17, 1935, reduced minimum seasonal payments to $71,000 for a five-year period, the differentials and back payments due to be paid with interest at the end of the period. Rates in the meantime were raised to $0.03525 and $0.088125 per 100 cubic feet for irrigation and domestic water, respectively. On February 26, 1945, a further agreement between District and City reduced the District's entitlement to 4,300 acre-feet per season, and set rates at $0.035, $0.075 and $0.03 per 100 cubic feet for irrigation, domestic and golf course irrigation water, respectively. Monthly payments to the City were established, limited to charges for water actually delivered to the District, with no minimum.

On September 29, 1941, the Santa Fe Irrigation District filed an application with the Division of Water Resources, No. 10292, for four second-feet of water from San Dieguito River, to be diverted from January 1 to July 1 of each year at a point below Hodges Dam. The application did not include provision for storage facilities. In

addition, the District may acquire all or a portion of rights, claimed by the Douglas Fairbanks Estate, to pump 1,000 acre-feet of water annually from the San Dieguito River bed on the Fairbanks Ranch.

During 1948 the District applied for entry into the San Dieguito County Water Authority, and use of its Colorado River supply. The application was approved by the Authority and the Metropolitan Water District, and in November 1948 by the electorate of the Santa Fe Irrigation District.

On the basis of 1946 assessed valuations, entitlement of the Santa Fe Irrigation District to the Colorado River supply is about 400 acre-feet per season, and will increase to about 700 acre-feet when the second barrel of the San Diego Aqueduct is constructed and the full supply made available for use. Up to the end of 1948 the District had received no Colorado River water. The San Diego County Water Authority presently charges $12.00 per acre-foot for Colorado River water delivered to member agencies, in addition to taxes and payments which are independent of water use. It is reported that the City of San Diego will charge the District $1.50 per acre-foot for transmission and necessary regulation of this foreign water in the San Dieguito System, plus a proportionate share of transmission and evaporation losses.

With proceeds from a $700,000 bond issue, the Santa Fe Irrigation District in 1924 purchased a water distribution system from the Santa Fe Land Improvement Company. Main pipe lines on Lockwood Mesa, and joint use of the Joint Gravity Pipe Line were also secured from the San Dieguito Mutual Water Company. Costs of these properties were $459,228, and remainder of the bond proceeds were spent on the distribution system over a period of years. The present system includes approximately 30 miles of steel and concrete mains from 12 to 30 inches in diameter, and some 50 miles of laterals ranging from two to ten inches in diameter. A little more than half the water consumed is lifted an average of 80 feet by 15 booster pumps. The system contains necessary regulating tanks and reservoirs, and all water is chlorinated. Services to consumers are completely metered.

Lands of the District are generally rolling and well drained. Soils, as classified by the United States Department of Agriculture, consist of loams or sandy loams near the coast, giving way to shallow adobe soils underlain with hardpan farther inland. Since development of most of the area has been to estate type units, irrigated acreage is limited by desire of property owners to retain lands in their natural state. An 18-hole golf course is maintained in connection with the somewhat exclusive community center at Rancho Santa Fe. Solana Beach is composed of beach cottages and highway commercial establishments, and has enjoyed growth during and since the war. According to a district report to the California District Securities Commission, irrigated lands totalled 2,760 acres in 1936. In 1948 a crop survey conducted by the Division of Water Resources showed an irrigated area of 2,379 acres within the District. Included were 1,629 acres of citrus fruits, 206 acres of avocados, 208 acres of truck crops, 215 acres of irrigated pasture, 27 acres of flowers and 94 acres of miscellaneous crops. Approximately 57 per cent of the irrigated lands, or 1,355 acres, lie within the San Dieguito Basin. The remaining 1,024 irrigated acres are in the drainage basin of Escondido Creek, to the north. Population increased from about 800 in 1936 to 2,000 in 1946. Water meters included 478 domestic and 517 irrigation services in 1946, while corresponding figures for 1936 were 253 and 400, respectively.

Average cost of water to the District in 1946 was $15.15 per acre-foot, and pumping costs for 2,060 acre-feet boosted were $2.34 per acre-foot. Consumers paid $0.03 per 100 cubic feet for irrigation water. Domestic rates per 100 cubic feet scaled from $0.15 for the first 1,000 cubic feet to $0.10 for the next 1,000, and $0.08 thereafter. The district tax levy amounted to $46,289, a $3.20 rate being assessed against 6,751 acres with valuation of $1,446,540.

Financial condition of the Santa Fe Irrigation District is now apparently sound, after some difficulties during the 1930s. At the end of 1946, outstanding bonds of the District amounted to $331,500, the original issue having been refinanced by the Federal Reconstruction Finance Corporation. On the same date, district assets totalled $897,638, and capital surplus was $504,651.

Present Water Utilization

Inspection of Table 18, showing seasonal water deliveries to Santa Fe Irrigation District, reveals no significant changes in recent years. While average utilization during the past two seasons was some 350 acre-feet in excess of the mean for the past five seasons, this is in large measure accounted for by marked deficiencies in precipitation during 1945-46 and 1946-47. It is therefore believed that present water utilization by Santa Fe Irrigation District averages about 3,280 acre-feet per season, the mean for the five seasons 1942-43 to 1946-47, inclusive.

TABLE 18

WATER FROM SAN DIEGUITO BASIN
DELIVERED TO SANTA FE IRRIGATION DISTRICT

Season	In Million Gallons	In Acre-Feet	Season	In Million Gallons	In Acre-Feet
1926-27	414	1,270	1937-38	936	2,872
1927-28	555	1,704	1938-39	946	2,903
1928-29	743	2,279	1939-40	947	2,907
1929-30	793	2,434	1940-41	869	2,667
1930-31	976	2,996	1941-42	836	2,564
1931-32	852	2,616	1942-43	1,017	3,121
1932-33	906	2,779	1943-44	1,047	3,212
1933-34	1,208	3,709	1944-45	914	2,806
1934-35	852	2,614	1945-46	1,220	3,746
1935-36	1,131	3,470	1946-47	1,144	3,509
1936-37	848	2,604			

About 85 per cent of water received by the District is used for irrigation, six per cent for domestic purposes, and losses average about eight per cent. A very minor quantity is sold outside the district boundaries.

Ultimate Water Utilization

While gross area of the Santa Fe Irrigation District is 10,106 acres, only about 7,200 acres are considered suitable for irrigated agriculture or domestic settlement. Of this susceptible land, it is anticipated that not more than 60 per cent, or about 4,300 acres, will actually be utilized under conditions of ultimate development. In keeping with the present trend, it is probable that the remainder will be preserved in its native state. Under these assumptions, the District will then be characterized by estate type residences and groves, and water use will be predominantly for irrigation, as it is at this time. Application of an average annual gross duty of water for irrigation of 1.3 acre-feet per acre to the foregoing 4,300 acres of suitable land results in a seasonal water requirement of about 5,600 acre-feet. If a further working allowance of ten per cent be provided as a factor of safety, the Santa Fe Irrigation District, under conditions of ultimate development of its present service area, should have available a firm water supply of approximately 6,200 acre-feet per season.

If it be assumed that the relationship between assessed valuations of the Santa Fe Irrigation District, San Diego County Water Authority and Metropolitan Water District will remain as in 1946, the Santa Fe Irrigation District will eventually receive its entitlement of about 700 acre-feet of Colorado River water per season. The District will also receive its present seasonal entitlement of 4,300 acre-feet of San Dieguito Basin water. It is considered probable that the District's requirement for supplementary water to meet its ultimate demand, in an estimated amount of 1,200 acre-feet per season, will be met by water from San Dieguito Basin. This follows from geographical situation of the Santa Fe Irrigation District relative to the basin and its established use of the water.

Ramona Irrigation District

This District was organized under the California Irrigation District Act on July 27, 1925, with principal purpose of providing a domestic water supply to the unincorporated community of Ramona. Approximately 36 of the 660 acres within the district boundaries are irrigated at this time. Water is obtained from shallow pumping wells in sands of the channel of Santa Maria Creek, north of the townsite.

At the time the District was formed, residents of Ramona depended upon many small wells to obtain a domestic supply of poor quality from shallow ground water beneath their properties. Bonds in amount of $91,000 were voted in May 1926 to purchase 165 acres of water-bearing land along Santa Maria Creek, develop a water supply thereon, and construct a distribution system. The purchase included a battery of eight existing wells, from 28 to 40 feet in depth, pumped by a six-inch centrifugal pump through a common suction. Included also were water rights resulting from a filing for 1,000 miner's-inches of the waters of Santa Maria Creek, made on March 4, 1912 by W. E. Woodward, and maintained thereafter, at least in part, by surface diversion and pumping from sands of the channel. The District added four wells to the field, and constructed a circular, concrete sump of 350,000-gallon capacity. From the sump, water was boosted 160 feet to a 100,000-gallon redwood tank situated some 1,500 feet to the southeast. The distribution system consisted of about eight miles of riveted and tubular steel pipe, ranging in diameter from three to ten inches. Water was first delivered through the system in August 1927.

It is reported that, within four years of completion of the works, trouble was experienced from corroding pipe lines, probably due to inferior or defective materials in the original installation, and in 1932 the vendor furnished without cost a considerable

amount of pipe for replacement. During the next six years most of the original distribu-
tion system was replaced, with State Emergency Relief Administration and Federal Works
Progress Administration assistance, cast-iron mains being substituted for the bulk of the
steel. In 1938 an 800,000 gallon, circular concrete reservoir was added, and from time
to time additional shallow wells have been sunk in the creek channel. Six wells were
drilled in the first half of 1947, bringing the total to 27. The District's water is un-
treated. All services are metered.

Lands of the Ramona Irrigation District lie between 1,400 and 1,500 feet in el-
evation, and, with exception of a little hillside, slope gently toward the channel of
Santa Maria Creek on the north. Soils, consisting mostly of sandy loams, are shallow and
lie over a subsoil of decomposed granite. Drainage is good and there is no alkali.

From a stage station in the Eighties, Ramona grew to a town of about 750 resi-
dents when the District was formed in 1925. Present development is toward residential
lots, business blocks and small homesites. There were over 250 individual properties in
the 460 acres assessed in 1946, largest holding being about ten acres. Along with a popu-
lation increase from about 900 in 1936 to an estimated 1,500 in 1946, metered water ser-
vices of the District have increased from 164 to 288. According to a crop survey con-
ducted by the Division of Water Resources in 1948, present irrigated acreage includes 21
acres of citrus, 9 acres of deciduous fruits, 2 acres of vineyard and 4 acres of pasture,
a total of 36 acres. Poultry raising is the most important agricultural pursuit in the
Ramona area.

Although the Ramona Irrigation District has experienced no serious financial
difficulties, its small size and limited valuation have prevented desirable development of
additional water supplies. At the end of 1946 the original bond issue of $91,000 was
still outstanding, retirement commencing in 1947. District assets totalled $120,847, and
capital surplus was $28,797. The tax levy amounted to $6,787, an $8.00 rate being asses-
sed against 460 acres, with valuation of $84,835. Water consumers were charged $0.60 per
1,000 cubic feet, with a minimum charge of $2.00 per month covering the first 1,000 cubic
feet.

Present Water Utilization
It is shown in Table 19 (page 85) that water utilized by Ramona Irrigation Dis-
trict has increased rather consistently from 1930-31 up to the present time. A marked
increase from about 200 to 300 acre-feet per season was experienced in 1945-46 over
1944-45, probably in large measure due to deficient rainfall in the latter season. Al-
though 1946-47 was also a dry season, draft dropped to about 230 acre-feet because of en-
forced restricted use, and inability of limited storage capacity in the sands of Santa
Maria Creek to maintain the higher rate. It is believed that average seasonal water util-
ization by Ramona Irrigation District is approximately 240 acre-feet, the mean for the
five-year period from 1942-43 to 1946-47, inclusive.

Ultimate Water Utilization
Ramona Irrigation District has reached the maximum development possible with
present sources of water supply, and some recession is currently indicated. When the Dis-
trict was organized, its safe seasonal yield from the sands of Santa Maria Creek was esti-
mated at 400 acre-feet. The experience of recent years proves this estimate to have been
optimistic, since pumping has been accompanied by excessive lowering of the water table,
resulting in severe restrictions on use.

TABLE 19

WATER PUMPED FROM SAN DIEGUITO BASIN
BY RAMONA IRRIGATION DISTRICT

Season	In Million Gallons	In Acre-Feet	Season	In Million Gallons	In Acre-Feet
1930-31	26.5	81.3	1938-39	56.5	174
1931-32	26.7*	82.1*	1939-40	61.7	189
1932-33	33.4	102	1940-41	51.8	159
1933-34	41.6	128	1941-42	66.9	205
1934-35	33.8	104	1942-43	72.4	222
1935-36	47.4	145	1943-44	71.7	220
1936-37	49.4	152	1944-45	64.0	196
1937-38	55.2	170	1945-46	99.6	306
			1946-47	76.1**	234**

Notes: * - Partially estimated.
       ** - Use restricted by drought.

Lack of financial capacity has so far precluded development of a supplemental water supply by the District. Such development is physically possible at the Hatfield dam site, on Hatfield Creek, two miles east of Ramona. An upstream extension of the present well field might also result in additional yield. At one time Ramona Irrigation District contemplated obtaining a supply of Colorado River water from the San Diego Aqueduct, and was an original member of the San Diego County Water Authority. It withdrew from the Authority, however, in 1946.

Under conditions of ultimate development, it is assumed that the 460 acres of land presently on the District's assessment rolls will be utilized for irrigated agriculture or residential purposes. With a seasonal duty of 1.3 acre-feet per acre, water requirements will then average about 600 acre-feet per season. If a further working allowance of ten per cent be provided as a factor of safety, the Ramona Irrigation District, under conditions of ultimate development of its present service area, should have available a firm water supply of approximately 700 acre-feet per season.

It is considered probable that the District's requirement for supplementary water to meet its ultimate demand, in an estimated amount of about 500 acre-feet per season, will be met by water from San Dieguito Basin. This follows from geographical situation of the Ramona Irrigation District within the basin and its established use of the water.

Del Mar Water, Light and Power Company

This private corporation supplies water for domestic and municipal uses in the unincorporated coastal community of Del Mar, immediately south of San Dieguito River. Its gross service area of 1,437 acres also covers the 22nd Agricultural District and Del Mar Turf Club property on bottom lands north of the river. Most of the habitable area is outside the San Dieguito watershed, and the Company's water supply from Lake Hodges is largely an export from San Dieguito Basin.

The Del Mar Water, Light and Power Company was incorporated in 1908, to provide water and electric power to purchasers of land from the South Coast Land Company, principal owner of the Del Mar townsite. In January 1908 this latter company had leased lands in San Dieguito Valley from the Santa Fe Land Improvement Company, with rights to sink wells and pump up to 50 miner's-inches of water therefrom "during any 24-hour period". This lease was assigned to the Del Mar Water, Light and Power Company, and in 1909 three wells were drilled on the property. The water was pumped through force mains about six miles to Del Mar, and there boosted to elevated tanks, from where a distribution system served consumers. By 1913 the number of services totalled 41, all domestic in nature, and maximum daily demand was about nine miner's-inches, or 120,000 gallons.

Under a contract dated November 1, 1925, superseding a similar agreement of June 15, 1925, the San Dieguito Water Company agreed to furnish the Del Mar Water, Light and Power Company a maximum of 724 acre-feet of water seasonally, delivery and measurement to be made by the San Dieguito Water Company at Del Mar, on the Lockwood Mesa-Torrey Pines Pipe Line. Rates were $0.04 and $0.10 per 100 cubic feet for irrigation and domestic water, respectively, with minimum seasonal charges scaled up to $12,600 after 1926-27. This contract was to terminate on October 31, 1957.

Also, on November 1, 1925, a contract between Del Mar Water, Light and Power Company, San Dieguito Water Company and San Diego County Water Company provided that the latter company furnish supplementary water from San Luis Rey watershed during drought periods, sufficient to assure the Del Mar Water, Light and Power Company a seasonal supply of 75 per cent of 724 acre-feet, this contract to terminate upon development of additional water supply in San Dieguito Basin by the San Dieguito Water Company. The City of San Diego had already, on October 5, 1925, agreed to assume obligations of the San Dieguito Water Company to the Del Mar Water, Light and Power Company under these contracts, and later perpetuated the 724 acre-foot entitlement of the Company.

Wells in San Dieguito Valley were abandoned with the advent of water from the San Dieguito System, and present works of the Company include only those in the vicinity of Del Mar. From a small regulating reservoir at the six-inch diameter intake from the Lockwood Mesa-Torrey Pines Pipe Line, water is pumped to a gravity-sand filter plant, and then to three small pressure regulating reservoirs on high ground back of the town. The distribution system, which extends to all parts of the service area, consists of about ten miles of pipe, ranging in diameter from two to twelve inches. Except for filtration, the water is untreated. All services are metered.

From the beginning, water use within the Company's service area has been almost exclusively domestic in nature, and it is all so classified at this time. Railroad, highway and street rights of way occupy 397 acres, and 330 acres are slough land in the river bottom, leaving only 710 acres to be supplied with water. The Company, however, plans to extend its service area to include an additional 80 acres adjacent to its southeasterly boundary. Assessed valuation within the present service area is about $1,125,000. Metered services have increased from 189 in 1936 to 281 in 1946, accompanying an increase in resident population from an estimated 650 to 900. In addition, there is a relatively large transient and seasonal population. Domestic rates charged by the Company are $0.187 per 100 cubic feet, with monthly minimum charge of $1.00 for the first 500 cubic feet.

Present Water Utilization

It is shown in Table 20 that water deliveries to Del Mar Water, Light and Power Company experienced a marked, sustained increase beginning with the season of 1943-44. For the five seasons from 1937-38 to 1941-42 the Company purchased an average of about 160 acre-feet seasonally from the City of San Diego, while the average for the past five seasons is approximately 250 acre-feet. It is believed that the high demands of 294 and 290 acre-feet, respectively, during the two most recent seasons reflect influence of unusually dry seasons, as well as development within the Company's service area, and are higher than average present seasonal water utilization. For this reason, the mean of the five-year period, 1942-43 to 1946-47, inclusive, or 250 acre-feet, is estimated to represent present seasonal water utilization by Del Mar Water, Light and Power Company.

Water losses of Del Mar Water, Light and Power Company average about eight per cent.

TABLE 20

WATER FROM SAN DIEGUITO BASIN DELIVERED
TO DEL MAR WATER, LIGHT AND POWER COMPANY

Season	In Million Gallons	In Acre-Feet	Season	In Million Gallons	In Acre-Feet
1926-27	77.2	237	1937-38	56.4	173
1927-28	90.0	276	1938-39	61.9	190
1928-29	90.5	278	1939-40	53.7	165
1929-30	99.2	304	1940-41	54.4	167
1930-31	64.6	198	1941-42	62.0	190
1931-32	53.9	165	1942-43	61.1	188
1932-33	44.2	136	1943-44	75.7	232
1933-34	50.2	154	1944-45	81.7	251
1934-35	43.7	134	1945-46	95.8	294
1935-36	53.8	165	1946-47	94.5	290
1936-37	61.6	189			

It should be noted that during 1946-47 approximately 180 acre-feet of water was sold by the Company to the San Dieguito Irrigation District, an amount not included in Table 20. This water, from the Company's entitlement in the San Dieguito System, was sold on an emergency basis with consent of the City of San Diego.

Ultimate Water Utilization

Under conditions of ultimate development it is anticipated that some 790 acres will constitute the built-up area actually served with water by Del Mar Water, Light and Power Company. In keeping with the present trend, the area should be characterized by suburban or rural type homes, in addition to existing hotel and resort culture. Consumptive use of water should be approximately equal to that of an equal area of irrigated agriculture. This conclusion is borne out by studies reported by the Division of Water

Resources in connection with its Raymond Basin Investigation in Los Angeles County, in which it was found that little change in unit values of consumptive use resulted with change from agricultural to suburban types of culture. Assuming, therefore, a seasonal duty of 1.3 acre-feet per acre, ultimate water requirements will average about 1,000 acre-feet per season. If a further working allowance of ten per cent be provided as a factor of safety, the Del Mar Water, Light and Power Company, under conditions of ultimate development of its service area as presently planned, should have available a firm water supply of approximately 1,100 acre-feet.

Entitlement of the Company in the San Dieguito System is 724 acre-feet per season. Although average seasonal use is now only about 35 per cent of the entitlement, additional capacity, above that obtained from the Lockwood Mesa-Torrey Pines Pipe Line, is required during periods of peak demand in the summer. Legal restrictions preclude the possibility of this private corporation obtaining a supplemental supply of Colorado River water from the San Diego Aqueduct. It is considered probable that the Company's requirement for supplementary water to meet its ultimate demand, in an estimated amount of about 400 acre-feet per season, will be met by water from San Dieguito Basin. This follows from geographical situation of the Del Mar Water, Light and Power Company relative to the basin and from its established use of the water.

City of San Diego

The City of San Diego contracted with Ed Fletcher and William G. Henshaw, on January 26, 1920, for water from the San Dieguito System, in an amount up to 3.0 million gallons per day, to be used in the City's La Jolla service area. Fletcher and Henshaw had on the same date obtained this water under a contract with the Santa Fe Land Improvement Company, a subsidiary of the San Dieguito Mutual Water Company, owners of the system. Fletcher and Henshaw later assigned their contract with the City to the San Dieguito Water Company, and it was superseded, on October 5, 1925, when the latter company effected a lease-sales contract with the City for the entire San Dieguito System, as heretofore discussed.

Present Utilization of Water from San Dieguito Basin

Status of the City's right to 3.0 million gallons per day from the San Dieguito System, as related to entitlements of the San Dieguito Committees, has not been determined by the courts. As is shown in Table 21 (page 89), the City has in no year utilized the full entitlement of approximately 3,360 acre-feet. Capacity of the transmission line is about 3.0 million gallons per day, but there are inevitably shut-downs which reduce the average figure. It is considered that the City of San Diego is presently utilizing water from San Dieguito Basin to the full capacity of existing transmission lines, and that this utilization is represented by the mean of deliveries for the five seasons from 1942-43 to 1946-47, inclusive, or 3,070 acre-feet per season.

Ultimate Utilization of Water from San Dieguito Basin

Safe yield of San Dieguito River, under present water supply development at Lake Hodges, is estimated at 6,700 acre-feet of water seasonally, the estimate being based on sustained supply with no deficiencies during the extreme drought period from 1896 to 1905, inclusive. The City of San Diego is obligated to deliver to the San Dieguito Committees a maximum of 8,224 acre-feet of water per season. At the same time the City has claim to 3.0 million gallons per day, or approximately 3,360 acre-feet per season, from Lake Hodges, plus its prorate of the 2,276 acre-feet released by Santa Fe Irrigation District under

terms of the agreement, dated February 26, 1945, between City and District, mentioned in
the section of this chapter concerning the Santa Fe Irrigation District. Under condi-
tions of ultimate development in service areas of the Committees, their contractual de-
mands on Lake Hodges water, plus the right of the City, will exceed safe yield of the
existing development.

TABLE 21

WATER FROM SAN DIEGUITO BASIN
DELIVERED TO CITY OF SAN DIEGO

Season	In Million Gallons	In Acre-Feet	Season	In Million Gallons	In Acre-Feet
1921*	191	587	1934-35	818	2,512
1922*	333	1,022	1935-36	834	2,559
1923*	512	1,570	1936-37	762	2,339
1924*	614	1,884	1937-38	849	2,605
1925*	618	1,898	1938-39	805	2,470
1926*	928	2,848	1939-40	875	2,677
1926-27	856	2,628	1940-41	893	2,741
1927-28	868	2,663	1941-42	1,057	3,243
1928-29	859	2,637	1942-43	1,012	3,106
1929-30	956	2,935	1943-44	1,012	3,106
1930-31	1,129	3,464	1944-45	1,022	3,135
1931-32	996	3,056	1945-46	1,016	3,117
1932-33	743	2,280	1946-47	939	2,880
1933-34	797	2,445			

Note: * - Calendar year.

Utilization of additional water from San Dieguito Basin by the City of San Diego
is therefore dependent upon development of additional safe yield by construction of con-
servation works in the watershed. In Bulletin No. 48 it was estimated that maximum sea-
sonal safe yield capable of development in San Dieguito Basin, by surface storage in the
303 square miles of drainage area above Hodges Dam, was 23,600 acre-feet for the 1896-1905
period of extreme drought. Further intensive studies in connection with the present in-
vestigation, discussed in detail in Chapter VII hereinafter, indicate a somewhat higher
figure for safe yield under maximum development of surface storage, or 28,100 acre-feet
seasonally for the 1896-1905 period. In consideration of probable future water require-
ments of the City of San Diego and its adjacent metropolitan area, heretofore discussed,
it is believed that all of this yield will be ultimately developed, and that an increment
of approximately 21,400 acre-feet of safe yield per season, over and above the 6,700 acre-
foot safe yield of the present Lake Hodges development, will be realized. This estimated
yield is in addition to San Dieguito Basin water developed and utilized by other than or-
ganized water service agencies, in amounts hereinafter estimated at 3,900 acre-feet per
season under both present and ultimate conditions of development.

Present entitlements of the Committees, totalling approximately 8,200 acre-feet per season, must, of course, be met by the City. In addition, the Ramona Irrigation District will continue to extract its present average yield of a little more than 200 acre-feet per season from the waters of Santa Maria Creek. Finally, it is considered probable that under conditions of ultimate development supplementary requirements of the Committees and of the Ramona Irrigation District, totalling an estimated 2,700 acre-feet seasonally above their present established supply of San Dieguito Basin and Colorado River water, will be met by water from San Dieguito Basin. This follows from the geographical situation of these agencies relative to the basin and their established use of the waters. Under these assumptions, use of surface waters of San Dieguito Basin by the Committees and Ramona Irrigation District under ultimate conditions will total approximately 11,100 acre-feet per season, and ultimate utilization of surface water from San Dieguito Basin by the City of San Diego is estimated at approximately 17,000 acre-feet per season, the remainder of the basin's estimated 28,100 acre-feet safe seasonal yield. This is again exclusive of San Dieguito Basin water developed and utilized by other than organized water service agencies.

It is shown in the section of Chapter VII pertaining to consumptive use that approximately 2,000 acre-feet of water per season on the average may be salvaged from present losses to consumptive use by native vegetation in San Pasqual Valley, under conditions of ultimate conservation development. This potential saving, by means of a program of pumping from the ground water sufficient to lower the water table below the root zone, may eventually be effected by and for the City of San Diego. On the assumption that this will be done, ultimate utilization of waters of San Dieguito Basin by the City, both surface and underground, is therefore estimated at 19,000 acre-feet per season, on the average.

Other Water Users

No records are available of utilization of San Dieguito Basin water, other than by the water service agencies discussed in the preceding section of this chapter. Remaining water users are largely individuals, although, as heretofore stated, there are also several small mutual water companies or associations, and three Indian reservations utilizing the water. Irrigation is the predominant use, but domestic water for the Del Dios subdivision and scattered settlements and farms is of minor importance.

Crop surveys conducted by the Division of Water Resources in 1948 show that an area of approximately 3,000 acres within the San Dieguito watershed, but outside the service areas of organized water service agencies, is presently irrigated by San Dieguito Basin water. Assuming an irrigation duty of 1.3 acre-feet per acre, a figure which experience has indicated as average for this region, it is estimated that about 3,900 acre-feet of San Dieguito Basin water are used seasonally by entities within the basin other than organized water service agencies.

Any further irrigation development in San Dieguito Basin by other than organized water service agencies will probably be limited to those lands overlying underground water sources from which water can be pumped economically. Lands overlying the principal groundwater sources, San Dieguito and San Pasqual valleys, are already developed to limits imposed either by available area or water supply. With proposed enlargement of Lake Hodges, the water supply of San Dieguito Valley will be reduced through reduction in spill from

that reservoir, and some retrogression in irrigated acreage may be expected. This development should not in itself have much effect on presently irrigated acreage in San Pasqual Valley, the greater part of which is above the reservoir flow line. In Santa Maria, Guejito and the small highland valleys, irrigation is generally limited now by available water supply, and only small increase is expected in the future. Such increase as may occur in these outlying areas will be largely offset by probable reduction in irrigation in San Dieguito Valley. In the aggregate, use of San Dieguito Basin water by others than organized water service agencies should average about the same under conditions of ultimate development as at this time, or approximately 3,900 acre-feet per season.

Export of Water

Present export of water from San Dieguito Basin is exclusively by diversion from Lake Hodges, by means of the Hodges Conduit and San Dieguito System. Exported water is delivered to the City of San Diego and to the several San Dieguito Committees for irrigation, domestic and municipal uses in areas along the coast both to the north and south of the San Dieguito River. Of deliveries from Lake Hodges to Santa Fe Irrigation District and Del Mar Water, Light and Power Company, portions are used inside the San Dieguito watershed and do not constitute export.

All San Dieguito Basin water consumed by the San Dieguito Irrigation District and by the City of San Diego constitutes export. Respective present seasonal utilization by these agencies is estimated at approximately 2,800 and 3,100 acre-feet, while under conditions of ultimate development it is estimated that the District will utilize 3,800 acre-feet seasonally, and that the City will realize 19,000 acre-feet seasonally.

In the case of Santa Fe Irrigation District, water utilization has heretofore been estimated to average about 3,280 acre-feet per season at present, increasing to approximately 6,200 acre-feet per season under conditions of ultimate development. Of this 6,200 acre-feet, however, it has heretofore been estimated that only 5,500 acre-feet will be San Dieguito Basin water, and that the remainder will be obtained from the Colorado River supply, under the District's membership in the San Diego County Water Authority. Based upon proportions of the irrigated area of the District inside and outside of the basin, it is estimated that approximately 57 per cent of water utilized by the District is consumed within the San Dieguito watershed, and that the remaining 43 per cent is export. This ratio is expected to be maintained under ultimate development of the District. It is estimated, therefore, that present export of San Dieguito Basin water to Santa Fe Irrigation District averages 1,400 acre-feet per season, and that this figure will rise to 2,400 acre-feet per season under conditions of ultimate development.

Of those 720 acres within the present service area of Del Mar Water, Light and Power Company which are considered suitable for residential or municipal use, less than 20 per cent lies within the San Dieguito Basin boundaries. Property of the 22nd Agricultural District and Del Mar Turf Club, in the San Dieguito River bottoms, however, is within the basin and constitutes an additional seasonal water demand. With exception of the foregoing fairgrounds and race track, present development at Del Mar is almost exclusively outside the basin. It is estimated that 95 per cent of the water presently utilized by the Company is exported from San Dieguito Basin, an average of about 240 acre-feet per season. Under expected ultimate development, relatively more of the Company's service area within the basin will be occupied, and it is estimated that approximately 90 per cent of

total water utilization of 1,100 acre-feet per season will then be export, averaging
1,000 acre-feet per season.

Average seasonal export of water from San Dieguito Basin, under present and
ultimate conditions of development, is summarized in Table 22.

TABLE 22

ESTIMATED AVERAGE SEASONAL EXPORT OF WATER
FROM SAN DIEGUITO BASIN

in Acre-Feet

Using Agency	Under Present Conditions	Under Ultimate Development
San Dieguito Irrigation District	2,800	3,800
Santa Fe Irrigation District	1,400	2,400
Del Mar Water, Light and Power Company	240	1,000
City of San Diego	3,100	19,000
TOTALS	7,540	26,200

Water Losses

Most of the water falling as precipitation on the watershed of San Dieguito
River is wasted or lost, largely from natural causes, and only a relatively small portion
is conserved for economic utilization. In order of their magnitude, principal losses
occur through consumptive use by native vegetation, including evaporation from soil and
natural water surfaces, surface runoff to the ocean, and evaporation from reservoirs.
Any additional yield of water which may ultimately be realized in San Dieguito Basin must
be developed through works designed to reduce one or more of these present major losses.
It will be shown hereinafter that, while some water presently lost by consumptive use of
native vegetation can be economically salvaged, the potential source of greatest additional
yield in the basin is that water presently running off into the ocean. At the same time,
any future conservation development involving construction of new reservoirs or enlarge-
ment of existing ones will inevitably increase present water losses by evaporation from
water surfaces.

Consumptive Use by Native Vegetation

By far the greater part of precipitation falling on the watershed of San Die-
guito River is lost to domestic, municipal or irrigation use or other forms of higher econ-
omic utilization through consumptive use by native vegetation. For purposes of this dis-
cussion, evaporation from soil and natural water surfaces is considered a part of such
consumptive use, and it also includes water consumed by natural grasses utilized for graz-
ing. The magnitude of these water losses is demonstrated by the fact that for the 50-year
normal period 1891-92 to 1940-41, inclusive, seasonal precipitation over the 303 square
miles of drainage area above Hodges Dam averaged 20.89 inches or 1.74 feet in depth, a to-
tal amount of about 337,400 acre-feet. During the same period, average seasonal runoff at
the dam was only about 40,700 acre-feet. The difference can only be accounted for by minor
domestic and irrigation use, amounting to about 2,700 acre-feet, and by consumptive use by
native vegetation, which must have aggregated approximately 294,000 acre-feet per season, on

the average. This latter use amounted to over 87 per cent of the water falling on the drainage area as precipitation, and was nearly 44 times greater than the safe yield presently developed at Hodges Dam for the San Dieguito System.

By analysis similar to the foregoing, an estimate of approximately 25,700 acre-feet seasonally was obtained for consumptive use by native vegetation on the 44 square miles of drainage area below Hodges Dam. Total average seasonal consumptive use by native vegetation on the entire San Dieguito watershed, including evaporation from soil and natural water surfaces, is therefore estimated at about 319,700 acre-feet, under present conditions.

Unfortunately, only a very small portion of the water lost by consumptive use of native vegetation is subject to salvage by means economically feasible at this time. It will be shown in Chapter VII, however, that on the average an estimated 2,000 acre-feet of water per season might be realized by means of a systematic program of pumping from the ground water in San Pasqual Valley, designed to lower the water table below the root zone of natural vegetation. In addition to this, some savings will be effected under complete conservation development of surface runoff through drying up of stream channels and minor ground water basins downstream from reservoirs. No attempt has been made, however, to evaluate losses to natural consumptive use under conditions of ultimate development.

Outflow to Ocean

While no measurements of actual discharge of San Dieguito River into the Pacific Ocean have been made, the record of flow of water over the spillway of Hodges Dam, some 12 miles upstream from the river's outlet, affords a basis for estimating outflow to the ocean. As is shown hereinafter, spill from the dam constitutes over 88 per cent of waters estimated to contribute directly to this waste to the ocean. The record of spill, shown in Table 23 (page 94), covers the 29-year period since construction of the dam, from 1918-19 to 1946-47, inclusive, and was computed jointly by the City of San Diego and the United States Geological Survey from records of reservoir operation.

Reference to Plate VII in Chapter V shows that the 29-year period of recorded spill at Hodges Dam happened to be one closely approximating a period of normal runoff. For this reason, the recorded average seasonal spill of 27,200 acre-feet is about what might have been expected during the adopted 50-year period of normal runoff from 1891-92 to 1940-41, inclusive. However, in order to reduce historical spill from Lake Hodges to that which would have occurred under present conditions, a correction is necessary because of increasing diversions above the dam. Since construction of Hodges Dam in 1919, utilization of San Dieguito Basin water by the San Dieguito Committees, Ramona Irrigation District and City of San Diego has averaged about 6,400 acre-feet per season, but their present use is estimated at approximately 9,700 acre-feet, an increase of about 3,300 acre-feet. Present use of San Dieguito Basin water by other than the above public agencies is estimated at about the same as average use during the period since 1919. Therefore, seasonal spill from Lake Hodges under present conditions is assumed to be 3,300 acre-feet less than the recorded historical average, or 23,900 acre-feet.

TABLE 23

WATER SPILLED FROM LAKE HODGES

Season	In Million Gallons	In Acre-Feet	Season	In Million Gallons	In Acre-Feet
1918-19	0	0	1933-34	0	0
1919-20	0	0	1934-35	0	0
1920-21	0	0	1935-36	0	0
1921-22	29,290	89,900	1936-37	42,330	129,910
1922-23	2,990	9,180	1937-38	25,080	76,970
1923-24	0	0	1938-39	9,020	27,680
1924-25	0	0	1939-40	1,500	4,600
1925-26	4,500	13,810	1940-41	51,130	156,920
1926-27	48,170	147,830	1941-42	9,540	29,280
1927-28	790	2,420	1942-43	10,580	32,470
1928-29	0	0	1943-44	2,320	7,120
1929-30	0	0	1944-45	1,420	4,360
1930-31	0	0	1945-46	740	2,270
1931-32	16,020	49,170	1946-47	0	0
1932-33	1,610	4,940			

29-Year Period, 1918-19 to 1946-47, Inclusive		In Million Gallons	In Acre-Feet
Total spill		257,030	788,830
Mean seasonal spill		8,860	27,200

An estimate of runoff originating below Hodges Dam was made from the mean relationship between runoff and average elevation of the watershed, previously established for numerous measured streams of San Diego County. A curve showing this relationship was developed during studies for Bulletin No. 48, in order to estimate runoff from minor streams. Including adjustment to the 50-year normal period 1891-92 to 1940-41, inclusive, it is found that average rate of seasonal runoff from the 23.8 square miles of tributary drainage area between Hodges Dam and the old Del Mar Gaging Station is 71.6 acre-feet per square mile. For the remaining 20.2 square miles below the station it is 68.3 acre-feet per square mile, and total runoff from the area below the dam averages about 3,100 acre-feet per season. With the previously derived spill from Lake Hodges, average seasonal inflow to the area downstream from Hodges Dam is therefore estimated at 27,000 acre-feet under present conditions of culture.

The above estimate of runoff from the area below Hodges Dam assumes average or normal conditions of consumptive use by native vegetation. For the service area of Santa Fe Irrigation District within the basin, it is assumed that the gravity irrigation supply from Lake Hodges is entirely consumed by transpiration and evaporation, with no net effect

on outflow to the ocean. On the floor of San Dieguito Valley, however, a considerable area is given over to irrigation from local wells, while the marsh near the coast is the source of consumptive use greater than average for native vegetation. Based upon a 1948 crop survey by the Division of Water Resources, it is estimated that the area irrigated from local underground sources is about 1,000 acres, for which net seasonal consumptive use of water is estimated at 1.3 acre-feet per acre, or a total of about 1,300 acre-feet. Approximately 200 acres of marsh land are estimated to consume 3.0 acre-feet per acre seasonally, in addition to direct precipitation, or a total of 600 acre-feet. Average seasonal outflow to the ocean is then obtained by subtracting this total increase of 1,900 acre-feet in consumptive use over that of normal native vegetation, from the previously estimated total inflow to the area below Hodges Dam.

Computations of outflow are shown in Table 24. It is estimated that under present conditions 25,100 acre-feet of water on the average flow into the Pacific Ocean from San Dieguito River and are wasted each season.

TABLE 24

OUTFLOW TO PACIFIC OCEAN FROM SAN DIEGUITO RIVER
UNDER PRESENT CONDITIONS

	Estimated Average Seasonal Amount in Acre-Feet
Historical spill from Lake Hodges	27,200
Increase in present over historical diversions above Hodges Dam	3,300
Spill from Lake Hodges under present conditions	23,900
Runoff originating below Hodges Dam	3,100
Total inflow to area below Hodges Dam	27,000
Net consumptive use by irrigated crops and marsh land in San Dieguito Valley	1,900
OUTFLOW TO PACIFIC OCEAN	25,100

Evaluation of outflow under conditions of ultimate development involves so many variable factors and conjectures that it has not been attempted in this study. It may be observed, however, that water presently wasting into the ocean is the principal source of additional yield from this watershed, and with probable future development of additional conservation works, and increased diversions for use both within and without the basin, outflow of water to the ocean will be greatly reduced.

Evaporation from Reservoirs

Under the present stage of water supply development in San Dieguito Basin, significant water losses are experienced through evaporation from Lake Hodges, and to a much smaller extent from San Dieguito Reservoir. Remaining reservoirs of the basin have an aggregate storage capacity of less than 500 acre-feet, and their losses through evaporation are so minor as to be of little consequence when considering water supply of the basin as a whole.

Gross evaporation from Lake Hodges, based upon floating evaporation pan measurements, has been recorded since the reservoir was placed in operation in 1919, and, as is shown in Table 25, has averaged 5,170 acre-feet per season. It has previously been noted that the 29-year period, 1918-19 to 1946-47, inclusive, since construction of Hodges Dam, was one of approximately normal runoff in San Dieguito River. Average seasonal evaporation from the reservoir during that period may be considered about normal for the long-time runoff period.

TABLE 25

GROSS EVAPORATION FROM LAKE HODGES

Season	In Million Gallons	In Acre-Feet	Season	In Million Gallons	In Acre-Feet
1918-19	204*	626*	1933-34	1,732	5,320
1919-20	912	2,800	1934-35	1,281	3,930
1920-21	978	3,000	1935-36	1,189	3,650
1921-22	1,876	5,760	1936-37	1,762	5,410
1922-23	2,416	7,410	1937-38	1,856	5,700
1923-24	2,095	6,430	1938-39	1,809	5,550
1924-25	1,573	4,830	1939-40	1,828	5,610
1925-26	1,768	5,430	1940-41	2,110	6,480
1926-27	1,904	5,840	1941-42	1,766	5,420
1927-28	1,892	5,810	1942-43	1,755	5,390
1928-29	2,033	6,240	1943-44	1,779	5,460
1929-30	1,902	5,840	1944-45	1,668	5,120
1930-31	1,776	5,450	1945-46	1,866	5,730
1931-32	2,026	6,220	1946-47	1,268	3,890
1932-33	1,825	5,600			

29-Year Period, 1918-19 to 1946-47, Inclusive	In Million Gallons	In Acre-Feet
Average seasonal evaporation	1,684	5,170

Note: * - Partial season.

Diversion and use of water from the San Dieguito System has increased over the period since 1919, so that the average amount of water stored in Lake Hodges would be less under present conditions than the historical average, and evaporation losses would be correspondingly reduced. However, even with the reservoir at high stages, a reduction of 3,300 acre-feet in storage, the full amount of increased seasonal use under present conditions over the historical average, would reduce the water surface area only about 90 acres. Gross seasonal evaporation at Lake Hodges is about five feet of water depth, so it may be

roughly estimated that average seasonal evaporation under present conditions would be approximately 450 acre-feet less than the historical average, or about 4,720 acre-feet.

Storage in San Dieguito Reservoir, used exclusively for regulation of San Dieguito Basin water, until recently was maintained at less than designed capacity in the interest of safety, and evaporation losses consequently averaged only about 200 acre-feet seasonally. With repairs to the dam completed in early 1948, storage has been increased and average seasonal evaporation will reach a figure of about 300 acre-feet, an amount assumed to be the average under present conditions.

Total average seasonal evaporation losses from San Dieguito Basin reservoirs are therefore estimated at approximately 5,000 acre-feet, or about 1,630 million gallons, under present conditions.

It is reasonable to believe that additional works to conserve the large increment of runoff in San Dieguito River now wasting into the ocean will be constructed in the future. The construction will involve new dams, or enlargement or completion of existing structures, to provide additional water storage capacity. With this increased capacity, and increase in average area of water surface, will come increased losses from evaporation. The magnitude of such losses under conditions of ultimate development can only be determined by complex reservoir studies based upon definite plans for the new works. The matter is further considered in Chapter VII, wherein a comparison is made between several plans for ultimate conservation development of the basin.

Summary of Water Utilization

Those estimates as to present and expected future disposition of the waters of San Dieguito Basin, which were developed and presented in preceding sections of this chapter, are summarized in Table 26.

TABLE 26

ESTIMATED AVERAGE SEASONAL UTILIZATION
OF WATERS OF SAN DIEGUITO BASIN

in Acre-Feet

	Under Present Conditions	Under Ultimate Development
By Water Service Agencies		
San Dieguito Irrigation District[a]	2,810	3,800
Santa Fe Irrigation District[e]	3,280	5,500
Ramona Irrigation District	240	700
Del Mar Water, Light and Power Company	250	1,100
City of San Diego[a]	3,070	19,000
Subtotals	9,650	30,100
By Other Water Users	3,900	3,900
TOTAL WATER UTILIZATION	13,550	34,000
Exported Water (included in above)	7,540	26,200

Water Losses	Under Present Conditions
Consumptive use by native vegetation[b]	319,700
Outflow to ocean	25,100
Evaporation from reservoirs	5,000
TOTAL	349,800

Notes: a - Excludes water supplied from sources outside San Dieguito Basin.
b - Includes water consumed by natural grasses utilized for grazing.

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Demands upon water sources within San Dieguito Basin, predominantly for export and use outside the watershed, have increased until they now approach and in some particular cases exceed the developed dependable supply. While no large future increase in utilization of this water within the basin is foreseen, continued growth is probable in the service area of present exporters, and their ultimate water requirements should be much greater than at this time. The pressure of future demands will probably be sufficient to assure eventual full development of all San Dieguito Basin water sources. At such time, it is estimated that total developed safe yield from the basin by all users will amount to an estimated 34,000 acre-feet seasonally. Of this total amount, it is believed that the City of San Diego will utilize about 19,000 acre-feet seasonally, after export to its service area.

Estimates presented in this chapter have been based upon the conception of safe yield, which implies in this instance a dependable water supply with no deficiencies during the extreme drought period from 1896 to 1905, inclusive. An additional yield of a secondary nature may be obtained, however, during certain series of years when runoff is above normal. Such secondary yield is dependent entirely upon the vagaries of the weather, and should not be considered in planning to meet the rigid domestic, municipal and irrigation water requirements of an area with characteristics such as those of the San Diego region.

CONSERVATION WORKS IN SAN DIEGUITO BASIN

Commencing along with the activity and speculation in irrigation enterprises
following completion of the railroad to San Diego County in the Eighties, a number of
plans have been advanced for more or less complete exploitation of the relatively large
water resources of San Dieguito Basin. However, until construction of Hodges Dam, started
in 1917 and completed in 1919 by the San Dieguito Mutual Water Company, all of the propos-
als had failed. Subsequent to the Hodges project, construction of a dam was started in
1927 at the Sutherland site by the City of San Diego, but after a series of misadventures
this conservation project was abandoned before completion.

Existing Development

Major water supply development in San Dieguito Basin is limited to Hodges Dam
and related diversion, regulation and transmission works, which are presently owned and
operated by the City of San Diego. Hodges Dam, a concrete multiple-arch structure, has a
crest length of 729 feet, is 130 feet in height, and has an overflow spillway 343 feet
long at the right end of the dam. The multiple-arch portion is 584 feet long, consisting
of 24 reinforced-concrete arches, with spans of 24 feet from center to center of plain con-
crete buttresses. The left 16 arches, comprising a length of 384 feet, have a crest ele-
vation of 330 feet. The remaining 200 feet of dam is capped with a curved concrete slab,
to form an overflow weir crest at elevation 315 feet. Remainder of the spillway was made
by excavating the right abutment, and constructing a concrete spillway crest and apron.
The spillway approach was deepened and improved in 1930, and a 50-foot concrete apron, 145
feet in length, was placed at its right end in 1936. Estimated capacity of the spillway
is 90,000 second-feet. The dam was reinforced in 1936 by constructing reinforced-concrete
web bracing in vertical planes between buttresses of alternate bays. Original construc-
tion cost was about $350,000, but spillway improvements in 1930, and strengthening of but-
tresses in 1936, both of which jobs were at the insistence of the State Engineer in inter-
ests of public safety, added materially to capital costs. Reservoir capacity was 37,699
acre-feet when built, but silting from a watershed area of 303 square miles has reduced
the storage to approximately 33,600 acre-feet. Water is released from Lake Hodges through
six openings at 10-foot vertical intervals in the upstream face of the dam. The 20-inch
openings, protected by fixed screens, are connected with 16-inch, cast-iron, vertical pipe
risers to 20-inch gate valves mounted on a 36-inch manifold. This in turn connects with
Hodges (or Carroll) Conduit, 4.65 miles in length, leading to San Dieguito Reservoir on
San Elijo Creek, a tributary of Escondido Creek. Most of this conduit is open concrete-
lined channel, but just below Hodges Dam there is a 300-foot length of 36-inch diameter,
wood-stave pipe, and several ravines are crossed by concrete siphons, or metal flumes on
timber trestles. Present conduit capacity is 17 second-feet or 11 million gallons per day.
Diversions for irrigation and domestic use are made at three points on Hodges Conduit.

San Dieguito Dam, built in 1918 by the San Dieguito Mutual Water Company, is
likewise of concrete multiple-arch construction. Its height is 51 feet, and crest length
650 feet, and it is provided with a siphon spillway of 1,150 second-foot capacity. There

is one foot of freeboard above the spillway lip at elevation 250 feet, at which elevation
storage capacity is 1,128 acre-feet. Drainage area above the dam is only 1.2 square
miles, and the reservoir is used only for regulation of the Hodges diversion. In the in-
terest of safety and under order of the State Engineer, storage was maintained for some
time at less than designed capacity. However, in early 1948 the City of San Diego rein-
forced the structure in order to utilize full capacity of the reservoir. The reinforce-
ment included guniting the upstream faces of the arches, adding pre-stressed tensile
steel to the arch groins, and constructing lateral counterforts on each side of the but-
tresses. Water is drawn from San Dieguito Reservoir by pipes at four points in the dam,
deliveries being made through pipe transmission lines to the San Dieguito and Santa Fe
irrigation districts, the Del Mar Water, Light and Power Company and to the City of San
Diego.

Only one of the conduits from San Dieguito Reservoir is actually included in the
San Dieguito System and owned by the City of San Diego, that terminating in the City's
La Jolla service area. Remaining conduits are owned and maintained by the San Dieguito
and Santa Fe irrigation districts, respectively. First section of the city-owned line,
known as the "Joint Gravity Pipe Line", is 8.9 miles in length, and leads southwesterly to
Lockwood Mesa Reservoir, with storage capacity of 378,000 gallons, at elevation 205 feet.
The line is constructed of 24-, 26- and 27-inch diameter, reinforced-concrete pipe and has
capacity of 3.9 million gallons per day, or 6.0 second-feet. The second conduit section,
the "Lockwood Mesa-Torrey Pines Pipe Line", extends southerly for 5.3 miles to the Torrey
Pines Filter Plant, at elevation 10 feet. The line is composed of varying lengths of
18-inch diameter, wood-stave, steel and cast-iron pipe, and 20-inch diameter concrete and
steel pipe, and has capacity of 3.0 million gallons per day, or 4.6 second-feet. From the
filter, water is pumped to an aerator at elevation 437 feet, from which it passes to Tor-
rey Pines Reservoir, a concrete-lined basin with storage capacity of 3.5 million gallons,
at elevation 431 feet. From the reservoir an 18-inch diameter, concrete pipe leads south-
erly about 26,000 feet to the La Jolla service area.

It has been estimated that during the most critical drought period of record,
from 1895-96 to 1904-05, inclusive, safe seasonal yield from present water supply develop-
ment in San Dieguito Basin would have been 6,700 acre-feet. During the less critical per-
iod, from 1916-17 to 1935-36, inclusive, used hereinafter in this chapter for purposes of
comparing several proposed plans for further conservation works, the existing development
in San Dieguito Basin would have had a "1917-36 firm" seasonal yield of 11,400 acre-feet.
This terminology is used in connection with sustained yield during this later period to
differentiate it from "safe" yield during the 1896-1905 drought.

Actual average seasonal draft from the San Dieguito System during the five-year
period 1942-43 to 1946-47, inclusive, was approximately 9,410 acre-feet. Of this seasonal
amount, about 3,070 acre-feet on the average was delivered to the City of San Diego, 3,280
acre-feet to the Santa Fe Irrigation District, 2,810 acre-feet to the San Dieguito Irriga-
tion District, and 250 acre-feet to the Del Mar Water, Light and Power Company. These
mean quantities are believed to represent approximately the average seasonal drafts of the
respective agencies from the waters of San Dieguito Basin under present conditions. As
has heretofore been stated, the City of San Diego is contractually committed to furnish
the above three agencies, the so-called "Committees", a total amount of water not to ex-
ceed 8,224 acre-feet per season. This amount, plus the present draft of approximately
3,100 acre-feet by the City, closely approaches 1917-36 firm yield of the existing develop-
ment, and greatly exceeds safe yield during the period from 1895-96 to 1904-05.

Complete Conservation Development

The objective of any plan for complete or ultimate development of water sources in San Dieguito Basin should be to conserve as large a percentage as possible of runoff now wasting into the ocean, as well as to effect any practicable salvage of water now wasted through consumptive use by natural vegetation in the watershed. It was shown in Chapter VI that these two major sources of present loss account for many times the water put to economic use.

As regards further conservation of surface runoff, one or more storage reservoirs with aggregate capacity of five to seven times the average seasonal runoff would be required for maximum conservation. This is illustrated by the fact that 33 per cent of total runoff at Hodges Dam during the 22-year period 1914-15 to 1935-36, inclusive, occurred in a single season, while combined runoff during the five largest seasons was nearly 78 per cent of the 22-year total. Yield studies show that 70 per cent of runoff measured at Hodges Dam in this period could have been conserved for beneficial use if sufficient storage capacity had been available. About 30 per cent of the runoff would have been lost by evaporation from reservoir surfaces. Complete development of surface runoff in San Dieguito Basin would require approximately 340,000 acre-feet of storage capacity. With this capacity, a 1917-36 firm yield of approximately 30,000 acre-feet seasonally could have been realized, and a safe yield of approximately 28,000 acre-feet during the seasons from 1894-95 to 1913-14, inclusive, which included the most critical drought period of record.

There are three principal reservoir sites on San Dieguito River and its tributaries, those designated as Hodges, Pamo and Sutherland, relative locations of which are shown on Plate VIII, "Conservation Works for Development of San Dieguito River". Inasmuch as approximately 40 per cent of total runoff in San Dieguito Basin originates below the Pamo site, any plan to attain maximum conservation must include provision for increasing capacity of the existing Lake Hodges.

Underground reservoirs in San Dieguito Basin, of sufficient capacity to warrant consideration in connection with possible use for seasonal and cyclic storage, are limited to those underlying San Dieguito and San Pasqual valleys. Use of the former by the City of San Diego is believed to be precluded because of its unfavorable geographic position and the possibility of salt water invasion if the water table is appreciably lowered. As regards San Pasqual Valley, such use of the ground-water basin is possible. Likewise, salvage by the City of water now wasted through consumptive use by natural vegetation would probably be limited to that occurring in San Pasqual Valley. This salvage might be effected through a system of pumping from the ground water sufficient to lower the water table below the root zone of native vegetation.

Yield from Surface Reservoirs

In the San Diego region, where water is so scarce and vital a commodity, the relative amounts of water to be realized from one or more of several proposed conservation works are of primary importance in comparing respective merits of the projects, and under certain circumstances may outweigh economic considerations. As regards surface reservoirs, principal factors entering into determination of yield, in order of their usual importance, are runoff, evaporation and draft. Runoff in San Dieguito Basin has been the subject of detailed discussion in Chapter V, and recorded or estimated monthly values of actual runoff at Hodges, Pamo and Sutherland dam sites, covering the period from 1912-13

to 1946-47, inclusive, are listed in Appendix F. For the yield studies the basic assumption was made that past runoff experience will, on the average, be repeated in the future. The remaining factors affecting yield of reservoirs in San Dieguito Basin, evaporation and draft, are discussed in later sections of this chapter.

Runoff Periods

The term "safe yield", as used in this report, refers to the amount of water which could have been supplied seasonally from a given source, without deficiency, throughout the critical period of dry years from 1895-96 to 1904-05, inclusive. However, in drawing comparisons between several reservoirs to develop maximum yield in San Dieguito Basin, it was desired to utilize the most reliable runoff information available. Although stream flow measurements were made on San Dieguito River at Bernardo from 1906 to 1912, it was not until 1912 that the United States Geological Survey began the comprehensive program of cooperative stream gaging and records on the river and its tributaries that has continued to the present date. While records at different stations are not continuous since 1912, runoff relationships established during periods of record, when combined with observations by the City of San Diego and others, provide sufficient basis for estimating monthly runoff during periods of missing record with acceptable accuracy for evaluating reservoir yield.

In the period since the beginning of reliable runoff record, an extended drought occurred during the 20 years from 1916-17 to 1935-36, inclusive. This critical period was preceded by two wet seasons, that of 1914-15 which was above normal, and the record flood season of 1915-16 in which runoff at Lake Hodges was more than 750 per cent of the long-time normal. The occurrence of these wet seasons assured that reservoirs would have been filled at the onset of the ensuing dry period, and imposed a definite objective on the yield studies; that is, the complete conservation of 1915-16 runoff. Basic yield studies of this report, therefore, were made to cover the period subsequent to 1914. Yield of the different reservoirs was fixed by the critical period 1916-17 to 1935-36, inclusive, and is herein referred to as "1917-36 firm yield". An exception is the existing Hodges Reservoir, which had a critical period from 1917-18 through 1920-21. The period studied began with the season of 1914-15, and yield as determined for the above critical periods held true through the 1944-45 season, the termination of studies.

In order to show relative severity of the critical period 1895-96 to 1904-05, inclusive, the most extreme of record, with that of the twenty years following 1915-16, semi-seasonal yield studies of the earlier period were made, based on estimated runoff. These less reliable runoff data for early years indicated that safe yield from the existing Lake Hodges during the drought from 1896 through 1905 would have been 59 per cent of 1917-36 firm yield. In the case of an enlarged Lake Hodges for complete conservation development of the basin, the corresponding ratio would have been 95 per cent. For other reservoirs, or combinations of reservoirs studied, the percentage varied between these extremes, dependent upon the amount and disposition of storage and method of reservoir operation.

Evaporation

Evaporation from reservoir surfaces in the San Diego region is a subject of primary importance in yield studies. For proposed larger capacity reservoirs at Lake Hodges the mean seasonal net evaporation loss was found to be over 40 per cent of corresponding 1917-36 firm seasonal yield. Net evaporation from a reservoir is the actual or gross evaporation less the precipitation on the reservoir surface.

PLATE VIII

LEGEND

PROPOSED RESERVOIR SITE
RESERVOIR SITE
EXISTING LAKE HODGES

CONSERVATION WORKS
FOR
DEVELOPMENT OF SAN DIEGUITO RIVER

SCALE OF MILES

PLATE VIII

LOCATION MAP
SCALE OF MILES

OCEANSIDE

ESCONDIDO

SAN LUIS REY R.

SANTA YSABEL IND. RESERVATION NO. 1

SANTA YSABEL INDIAN RESERVATION NO. 2

HENSHAW RESERVOIR

T.11 S.

T.12 S.

PINE MTN

MESA GRANDE

BLACK MTN

Black Canyon

PAMO RESERVOIR SITE

MESA GRANDE IND. RES.

SANTA YSABEL INDIAN RESERVATION NO. 2

VOLCAN MOUNTAIN

Creek

PACIFIC OCEAN

Batiquitos Lagoon

LEUCADIA

ENCINITAS

CARDIFF

SOLANA BEACH

DEL MAR

Escondido Creek

R.4 W

San Dieguito Res.

SAN DIEGUITO

LAKE HODGES

PUMPING PLANT

RANCHO SANTA FE

San Elijo Lagoon

Lake Ranch

DEL DIOS

Bernardo

SANTA

YSABEL

Creek

Guejito Creek

Santa Ysabel Creek

Rodeo Creek Canyon

Black Canyon

SUTHERLAND RESERVOIR SITE

Santa Ysabel

WITCH CREEK

SANTA YSABEL

JULIAN

R.4 E.

T.12 S.

SUTHERLAND–SAN VICENTE PIPE LINE

PAMO PIPE LINE

RIVER

FILTRATION PLANT

HODGES–CHESTERTON TANK PIPE LINE

Santa Maria Creek

O RAMONA

Hatfield Creek

Witch Creek

SAN DIEGO RIVER

T.13 S.

R.3 E.

San Diego

AQUEDUCT

Los Penasquitos Canyon

CHESTERTON TANK

SCALE IN MILES

San Vicente

SAN BERNARDINO MERIDIAN

SAN VICENTE RESERVOIR

CAPITAN GRANDE INDIAN RESERVATION

EL CAPITAN RESERVOIR

SAN DIEGO RIVER

T.14 S.

R.3 W   R.2 W   R.1 W   R.1 E   R.2 E

LEGEND
PROPOSED RESERVOIR SITE
RESERVOIR SITE
EXISTING LAKE HODGES

CONSERVATION WORKS
FOR
DEVELOPMENT OF SAN DIEGUITO RIVER

SCALE OF MILES

Evaporation studies made in connection with Bulletin No. 48 indicated that the depth of evaporation from a reservoir surface increases with distance from the coast and with rise in elevation. It is apparent that the Pacific Ocean moderates the coastal climate by reducing summer temperatures and raising the humidity. Toward the interior, summer temperatures become higher and the humidity lower, while reservoirs near the crest of the mountains, such as Morena and Cuyamaca, are exposed to dry hot winds from the desert which further increase the rate of evaporation.

In estimating evaporation losses from proposed reservoirs in San Dieguito Basin, use was made of records of observed gross evaporation at Hodges, Morena, Barrett, Henshaw and Cuyamaca reservoirs, data for which are summarized in Table 27. These records are based upon measurements by floating and land evaporation pans, as indicated in the table, to which measurements suitable coefficients have been applied in order to evaluate actual evaporation from reservoir surfaces. For Lake Hodges a record of monthly evaporation since February 1919, when the reservoir was placed in operation, was obtained from the City of San Diego. Records for Morena and Barrett were likewise originally obtained from the City, and the Cuyamaca record was furnished by the La Mesa, Lemon Grove and Spring Valley Irrigation District. The record of evaporation at Lake Henshaw was obtained from the San Diego County Water Company.

TABLE 27

GROSS EVAPORATION FROM RESERVOIRS
IN SAN DIEGO COUNTY

Month	Measured										Estimated			
	Lake Hodges		Lake Henshaw		Barrett Reservoir		Morena Reservoir		Cuyamaca Reservoir		Pamo Dam Site		Sutherland Dam Site	
	Percent of Mean Seasonal	Mean Depth in Inches	Percent of Mean Seasonal	Mean Depth in Inches	Percent of Mean Seasonal	Mean Depth in Inches	Percent of Mean Seasonal	Mean Depth in Inches	Percent of Mean Seasonal	Mean Depth in Inches	Percent of Mean Seasonal	Mean Depth in Inches	Percent of Mean Seasonal	Mean Depth in Inches
October	8.31	4.76	8.32	5.66	8.96	5.90	8.60	5.78	9.07	6.60	8.63	5.52	8.63	5.78
November	6.40	3.67	5.48	3.73	5.82	3.83	5.98	4.02	6.12	4.45	5.76	3.69	5.76	3.86
December	4.71	2.70	3.40	2.31	3.98	2.62	4.42	2.97	4.00	2.91	3.93	2.52	3.93	2.63
January	4.14	2.37	2.98	2.03	3.57	2.35	3.51	2.36	3.85	2.80	3.35	2.14	3.35	2.24
February	3.88	2.22	3.20	2.18	3.49	2.30	3.21	2.16	5.04	3.67	3.30	2.11	3.30	2.21
March	6.09	3.49	5.16	3.51	5.44	3.58	4.98	3.35	6.38	4.64	5.19	3.32	5.19	3.48
April	7.42	4.25	7.04	4.79	7.32	4.82	6.77	4.55	6.49	4.72	7.04	4.51	7.04	4.72
May	10.04	5.75	10.41	7.08	10.05	6.06	9.01	6.06	9.28	6.75	9.82	6.28	9.82	6.58
June	11.43	6.55	12.14	8.26	12.02	7.92	12.60	8.47	11.92	8.67	12.26	7.85	12.26	8.21
July	13.61	7.79	15.17	10.32	14.33	9.43	14.72	9.90	13.61	9.90	14.74	9.44	14.74	9.88
August	13.09	7.50	14.68	9.98	13.97	9.19	14.06	9.45	13.01	9.46	14.24	9.11	14.24	9.54
September	10.88	6.23	12.02	8.18	11.05	7.27	12.14	8.16	11.23	8.18	11.74	7.51	11.74	7.87
Seasonal		57.28		68.03		65.82		67.23		72.75		64.00		67.00
Period of Record	1920-1944 25 years		1923-1937 15 years		1922-1933 12 years		1916-1933 18 years		1912-1933 22 years		------ ------		------ ------	
Elevation in Feet	400		2,600		1,600		3,000		4,600		1,100		2,100	
Distance from Coast in Miles	10		33		29		36		42		25		30	
Authority	City of San Diego		San Diego County Water Company		City of San Diego		City of San Diego		La Mesa, Lemon Grove and Spring Valley Irrigation District		Estimated by Division of Water Resources		Estimated by Division of Water Resources	
Pan:														
Floating	3' x 3' x 18"		3' x 3' x 18"		3' x 3' x 18"		3' x 3' x 18"[a]		3' x 3' x 18"[b]		------		------	
Ground	------		3' x 3' x 18"		------		------		3' x 3' x 18"[c]		------		------	

Notes: a - Pan dimensions from 1916 to 1919, inclusive, were 4.63' x 7.31'.
  b - 1912-1920, inclusive.
  c - 1912-1933, inclusive.

Evaporation studies made in connection with Bulletin No. 48 indicated that the depth of evaporation from a reservoir surface increases with distance from the coast and with rise in elevation. It is apparent that the Pacific Ocean moderates the coastal climate by reducing summer temperatures and raising the humidity. Toward the interior, summer temperatures become higher and the humidity lower, while reservoirs near the crest of the mountains, such as Morena and Cuyamaca, are exposed to dry hot winds from the desert which further increase the rate of evaporation.

In estimating evaporation losses from proposed reservoirs in San Dieguito Basin, use was made of records of observed gross evaporation at Hodges, Morena, Barrett, Henshaw and Cuyamaca reservoirs, data for which are summarized in Table 27. These records are based upon measurements by floating and land evaporation pans, as indicated in the table, to which measurements suitable coefficients have been applied in order to evaluate actual evaporation from reservoir surfaces. For Lake Hodges a record of monthly evaporation since February 1919, when the reservoir was placed in operation, was obtained from the City of San Diego. Records for Morena and Barrett were likewise originally obtained from the City, and the Cuyamaca record was furnished by the La Mesa, Lemon Grove and Spring Valley Irrigation District. The record of evaporation at Lake Henshaw was obtained from the San Diego County Water Company.

TABLE 27

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IN SAN DIEGO COUNTY

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	Lake Hodges		Lake Henshaw		Barrett Reservoir		Morena Reservoir		Cuyamaca Reservoir		Pamo Dam Site		Sutherland Dam Site	
	Percent of Mean Seasonal	Mean Depth in Inches	Percent of Mean Seasonal	Mean Depth in Inches	Percent of Mean Seasonal	Mean Depth in Inches	Percent of Mean Seasonal	Mean Depth in Inches	Percent of Mean Seasonal	Mean Depth in Inches	Percent of Mean Seasonal	Mean Depth in Inches	Percent of Mean Seasonal	Mean Depth in Inches
October	8.31	4.76	8.32	5.66	8.96	5.90	8.60	5.78	9.07	6.60	8.63	5.52	8.63	5.78
November	6.40	3.67	5.48	3.73	5.82	3.83	5.98	4.02	6.12	4.45	5.76	3.69	5.76	3.86
December	4.71	2.70	3.40	2.31	3.98	2.62	4.42	2.97	4.00	2.91	3.93	2.52	3.93	2.63
January	4.14	2.37	2.98	2.03	3.57	2.35	3.51	2.36	3.85	2.80	3.35	2.14	3.35	2.24
February	3.88	2.22	3.20	2.18	3.49	2.30	3.21	2.16	5.04	3.67	3.30	2.11	3.30	2.21
March	6.09	3.49	5.16	3.51	5.44	3.58	4.98	3.35	6.38	4.64	5.19	3.32	5.19	3.48
April	7.42	4.25	7.04	4.79	7.32	4.82	6.77	4.55	6.49	4.72	7.04	4.51	7.04	4.72
May	10.04	5.75	10.41	7.08	10.05	6.61	9.01	6.06	9.28	6.75	9.82	6.28	9.82	6.58
June	11.43	6.55	12.14	8.26	12.02	7.92	12.60	8.47	11.92	8.67	12.26	7.85	12.26	8.21
July	13.61	7.79	15.17	10.32	14.33	9.43	14.72	9.90	13.61	9.90	14.74	9.44	14.74	9.88
August	13.09	7.50	14.68	9.98	13.97	9.19	14.06	9.45	13.01	9.46	14.24	9.11	14.24	9.54
September	10.88	6.23	12.02	8.18	11.05	7.27	12.14	8.16	11.23	8.18	11.74	7.51	11.74	7.87
Seasonal		57.28		68.03		65.82		67.23		72.75		64.00		67.00
Period of Record	1920-1944 25 years		1923-1937 15 years		1922-1933 12 years		1916-1933 18 years		1912-1933 22 years		------ ------		------ ------	
Elevation in Feet	400		2,600		1,600		3,000		4,600		1,100		2,100	
Distance from Coast in Miles	10		33		29		36		42		25		30	
Authority	City of San Diego		San Diego County Water Company		City of San Diego		City of San Diego		La Mesa, Lemon Grove and Spring Valley Irrigation District		Estimated by Division of Water Resources		Estimated by Division of Water Resources	
Pan:														
Floating	3' x 3' x 18"		3' x 3' x 18"		3' x 3' x 18"		3' x 3' x 18"e		3' x 3' x 18"b		------		------	
Ground	------		3' x 3' x 18"		------		------		3' x 3' x 18"c		------		------	

Notes: a - Pan dimensions from 1916 to 1919, inclusive, were 4.63' x 7.31'.
b - 1912-1920, inclusive.
c - 1912-1933, inclusive.

In connection with yield studies of reservoirs at Lake Hodges, evaporation losses during the period of record were estimated on the basis of observed net depth of evaporation on the existing reservoir, by subtracting recorded rainfall from measured gross evaporation. For months prior to February 1919, evaporation was estimated by subtracting estimated monthly rainfall from average monthly gross evaporation, as recorded through the 25 complete seasons following 1919.

At Sutherland and Pamo dam sites, mean gross depth of seasonal evaporation was estimated by graphical interpolation of average recorded seasonal values at Hodges, Barrett, Henshaw and Cuyamaca reservoirs. Semi-logarithmic plots of average gross seasonal depths of evaporation at these reservoirs, against elevation and distance from the coast, resulted in the relatively smooth curves shown on Plate IX, "Variation of Evaporation with Elevation and Distance from the Coast for Reservoirs in San Diego County". For Pamo Reservoir, values taken directly from the graphs, on the basis of both elevation and distance from the coast, differ by only one-half inch in depth of average seasonal gross evaporation. Corresponding difference for the Sutherland site is 1.1 inches of depth. The nearest even inch was selected for estimating gross seasonal depth of evaporation for use in yield studies of reservoirs at these sites.

Monthly distribution of estimated seasonal gross evaporation at Pamo and Sutherland was taken as the average of mean monthly percentages for Henshaw, Morena and Barrett reservoirs. These three reservoirs are more nearly comparable to Pamo and Sutherland, as regards elevation and distance inland, than are other reservoirs in San Diego County.

Net depth of evaporation for the Pamo and Sutherland sites was computed from monthly gross depth of evaporation, derived as outlined above, and from estimated monthly rainfall.

Total quantitative monthly net evaporation loss from each reservoir was finally obtained by multiplying the average water surface area during the month by the estimated or recorded net depth of evaporation for the same month.

Draft from Reservoirs

In making yield studies for proposed conservation works, the factors of runoff and evaporation, which are inherently subject almost exclusively to the laws of nature, were evaluated upon the assumption that past experience would, on the average, be repeated in the future. The factor of draft, however, is governed by anticipated demands under conditions of present or future cultural development, and may be affected by characteristics of transmission and distribution works.

It was found that under certain combinations of proposed reservoirs in San Dieguito Basin, and under certain methods of operation, 1917-36 firm yield from Lake Hodges would have been less than assumed use of this water under present conditions by the San Dieguito Committees, taken as 5,300 acre-feet per season. When 1917-36 firm yield from Lake Hodges was less than 5,300 acre-feet per season, therefore, seasonal draft was distributed in accordance with weighted average monthly use by the Committees during the five-year period from 1939-40 through 1943-44. It must, of course, be assumed that in a development wherein yield from Lake Hodges would be less than entitlements of the Committees, the difference would be supplied from upstream storage. When 1917-36 firm yield from Lake Hodges exceeded 5,300 acre-feet per season, that amount was distributed as before, but the
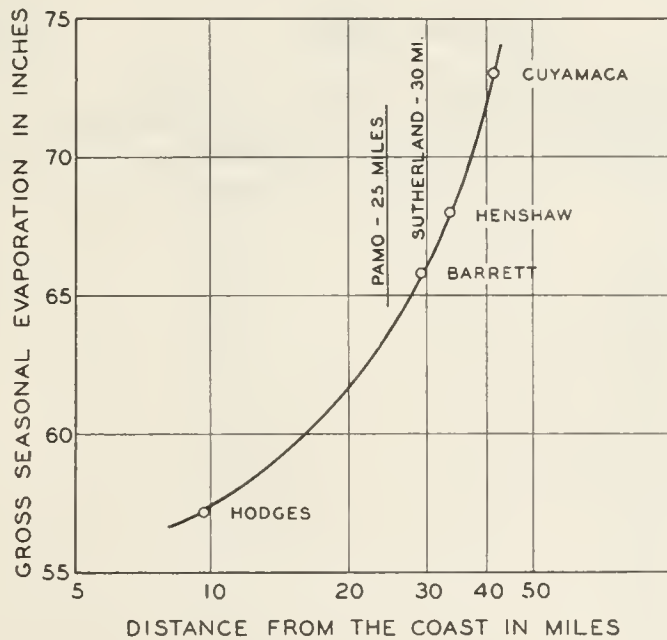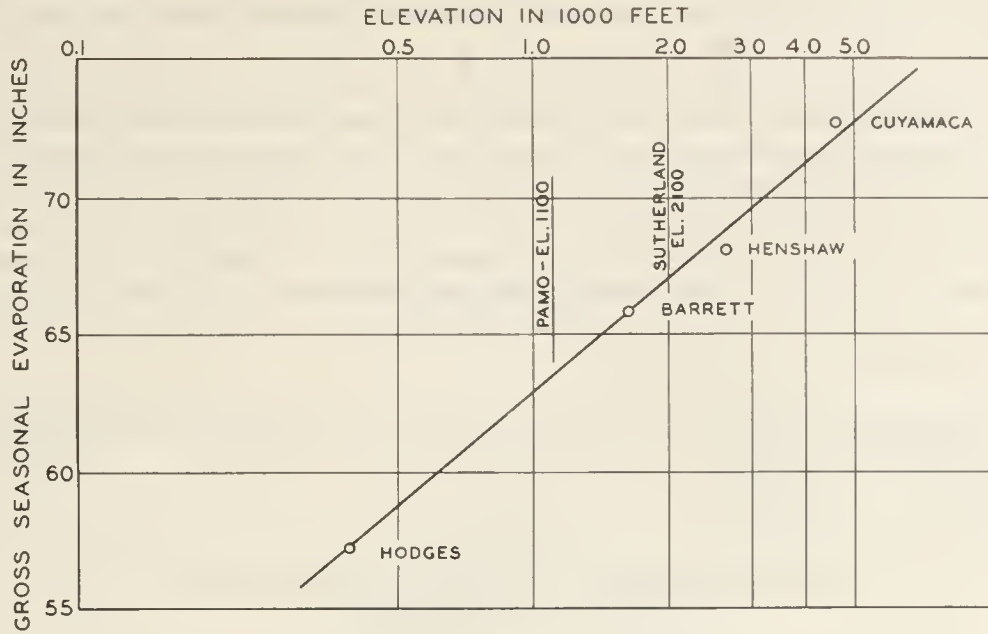
PLATE IX

VARIATION OF EVAPORATION WITH
ELEVATION AND DISTANCE FROM THE COAST
FOR RESERVOIRS IN SAN DIEGO COUNTY

excess above 5,300 acre-feet was divided monthly, in accordance with average monthly consumption of water by the City of San Diego during the five-year period from 1941 through 1945.

In making yield studies for Pamo and Sutherland reservoirs, deliveries from which were assumed to be exclusively to the City of San Diego by means of gravity transmission lines, all draft was considered to be municipal in nature, and monthly distribution was made in accordance with average monthly consumption of water by the City of San Diego during the five-year period from 1941 through 1945. An exception to this general rule was made in the case of yield studies for secondary water from Sutherland Reservoir, in which the diversion was assumed to be maintained to the full capacity of a 36-inch diameter outlet pipe, whenever possible.

The assumed monthly distribution of drafts from reservoirs in San Dieguito Basin are listed in Table 28.

TABLE 28

ASSUMED DISTRIBUTION OF DRAFTS FROM RESERVOIRS
IN SAN DIEGUITO BASIN

In Per Cent of Seasonal Totals

Month	From Lake Hodges		From Pamo and Sutherland* Reservoirs
	To San Dieguito Committees, Yield up to 5,300 Acre-Feet per Season	To City of San Diego, Yield over 5,300 Acre-Feet per Season	To City of San Diego
October	9.64	9.00	9.00
November	7.31	7.81	7.81
December	3.95	7.48	7.48
January	2.44	6.45	6.45
February	1.86	5.90	5.90
March	2.93	6.83	6.83
April	4.54	7.43	7.43
May	11.07	9.31	9.31
June	13.74	9.43	9.43
July	14.67	10.44	10.44
August	14.89	10.42	10.42
September	12.96	9.50	9.50
TOTALS	100.00	100.00	100.00

Note: * - Applied only to 1917-36 firm yield from Sutherland Reservoir. For secondary water from Sutherland Reservoir, draft was maintained at 42.4 second-feet, whenever possible.

Yield

Utilizing data on runoff, evaporation and draft, detailed monthly studies were made to determine yield of reservoirs in San Dieguito Basin, under various assumptions as to capacities, combinations of reservoirs and methods of operation. Average seasonal results of these studies are listed in Table 29, and shown graphically on Plate X, "Estimated Seasonal Yield from Reservoirs in San Dieguito Basin, 1914-15 to 1944-45, Inclusive."

TABLE 29

ESTIMATED SEASONAL YIELD FROM RESERVOIRS
IN SAN DIEGUITO BASIN

1914-15 to 1944-45, Inclusive

Study No.	Reservoirs	Storage Capacity in Acre-Feet				1917-36 Firm Yield in Acre-Feet				Secondary Water[a] Average Yield in Acre-Feet	Supplemental Yield Over That of Present Development in Acre-Feet		
		Hodges	Pamo	Sutherland	Total	Hodges	Pamo	Sutherland	Total	Sutherland	1917-36 Firm Yield	Secondary Water	Total
A-1	Hodges	33,600	0	0	33,600	11,400	0	0	11,400	0	0	0	0
A-2	Hodges	104,500	0	0	104,500	20,200	0	0	20,200	0	8,800	0	8,800
A-3	Hodges	157,300	0	0	157,300	24,000	0	0	24,000	0	12,600	0	12,600
A-4	Hodges	224,800	0	0	224,800	26,800	0	0	26,800	0	15,400	0	15,400
A-5	Hodges	338,000[b]	0	0	338,000	29,400	0	0	29,400	0	18,000	0	18,000
B-1	Hodges and Pamo	33,600	90,000	0	123,600	4,500	18,000	0	22,500	0	11,100	0	11,100
B-2	Hodges and Pamo	33,600	135,000	0	168,600	4,500	20,300	0	24,800	0	13,400	0	13,400
B-3	Hodges and Pamo	33,600	163,400[b]	0	197,000	4,500	21,400	0	25,900	0	14,500	0	14,500
B-4	Hodges and Pamo	174,400[c]	163,400	0	337,800	8,800	21,400	0	30,200	0	18,800	0	18,800
C-1	Hodges and Sutherland	33,600	0	36,700	70,300	6,600	0	9,800	16,400	0	5,000	0	5,000
C-2	Hodges and Sutherland	104,500	0	36,700	141,200	13,100	0	9,800	22,900	0	11,500	0	11,500
C-3	Hodges and Sutherland	157,300	0	36,700	194,000	16,400	0	9,800	26,200	0	14,800	0	14,800
C-4	Hodges and Sutherland	224,800	0	36,700	261,500	17,800	0	9,800	27,600	0	16,200	0	16,200
C-5	Hodges and Sutherland	301,700[b]	0	36,700	338,400	19,400	0	9,800	29,200	0	17,800	0	17,800
D-1	Hodges and Sutherland	33,600	0	36,700	70,300	6,600	0	0	6,600	14,100	-4,800	14,100	9,300
D-2	Hodges and Sutherland	33,600[d]	0	36,700	70,300	11,400	0	0	11,400	10,100	0	10,100	10,100
D-3	Hodges and Sutherland	33,600[e]	0	36,700	70,300	11,400	0	0	11,400	8,800	0	8,800	8,800
D-4	Hodges and Sutherland	33,600[f]	0	36,700	70,300	11,400	0	0	11,400	8,200	0	8,200	8,200
D-5	Hodges and Sutherland	104,500	0	36,700	141,200	13,000	0	0	13,000	14,100	1,600	14,100	15,700
D-6	Hodges and Sutherland	157,300	0	36,700	194,000	14,800	0	0	14,800	14,100	3,400	14,100	17,500
D-7	Hodges and Sutherland	224,800	0	36,700	261,500	16,200	0	0	16,200	14,100	4,800	14,100	18,900
D-8	Hodges and Sutherland	277,800[b]	0	36,700	314,500	17,200	0	0	17,200	14,100	5,800	14,100	19,900
E-1	Pamo, Sutherland and present Hodges	33,600	90,000	36,700	160,300	4,500	8,200	0	12,700	14,100	1,300	14,100	15,400
F-1	Pamo, Sutherland and present Hodges	33,600	127,800	36,700	198,100	4,500	11,100	9,800	25,400	0	14,000	0	14,000

Notes: a - Average seasonal yield from December 1914 to November 1936, inclusive, with maximum diversion to capacity of
     36-inch diameter pipe line, or 42.4 second-feet.
    b - Minimum capacity to avoid spill in 1915-16. No spill from 1915-16 to 1944-45, inclusive.
    c - No spill in 1915-16. Spill in 1941 and 1942. (Capacity of 205,000 acre-feet required to avoid spill in 1942.)
    d - 500 acre-feet dead storage in Hodges. 13,500 acre-feet reserve storage in Sutherland for release to Hodges.
    e - 1,500 acre-feet dead storage in Hodges. 17,200 acre-feet reserve storage in Sutherland for release to Hodges.
    f - 5,000 acre-feet dead storage in Hodges. 20,500 acre-feet reserve storage in Sutherland for release to Hodges.

Significant conclusions to be derived from the yield studies covering the period from 1914-15 to 1944-45, inclusive, are summarized below:

a. The existing San Dieguito System development had a 1917-36 firm seasonal yield of 11,400 acre-feet.

b. Complete development for full conservation of surface runoff in San Dieguito Basin above Hodges Dam would have required a total of approximately 340,000 acre-feet of storage capacity. Resultant 1917-36 firm seasonal yield would have been about 30,000 acre-feet, or some 60 per cent of average runoff at Hodges Dam.

c. Under various combinations of storage capacity as divided between Hodges, Pamo and Sutherland reservoirs, but involving the same aggregate capacity within the basin, 1917-36 firm yield would have been approximately equal, provided that Lake Hodges had a sufficient capacity to prevent spill.

d. Any plan for complete conservation of surface runoff in San Dieguito Basin would have necessarily included provision for large increase in storage capacity at Lake Hodges. If all runoff above Pamo had been withheld, excepting only that required for consumptive uses in San Pasquel Valley, storage capacity of 174,400 acre-feet would have been required at Lake Hodges to avoid spill in 1915-16, while 205,000 acre-feet would have been necessary to prevent spill in 1942-43. It follows that under any plan for complete development Lake Hodges should have had storage capacity of not less than 174,400 acre-feet. A reservoir of this capacity would have developed 1917-36 firm seasonal yield of 8,800 acre-feet, utilizing only the runoff below Pamo. Operated by itself, with runoff from the entire tributary watershed, 1917-36 firm seasonal yield would have been approximately 25,000 acre-feet, or 83 per cent of that under complete conservation development in the watershed.

e. With total storage capacity of 314,500 acre-feet in the basin, made up of 277,800 acre-feet at Lake Hodges and 36,700 acre-feet at Sutherland, average seasonal yield would have been 31,300 acre-feet. While 17,200 acre-feet of this total amount would have been 1917-36 firm seasonal yield from Lake Hodges, the remaining 14,100 acre-feet would have been average seasonal yield of secondary water from Sutherland Reservoir. Value of the secondary water would have been dependent upon the capacity of the City of San Diego to use the water approximately at the time of its occurrence.

Because of its relatively reliable runoff data, the period subsequent to 1914 was chosen for yield studies used in this investigation to compare reservoirs in San Dieguito Basin. The period prior to 1914, however, extending back to include the extremely severe drought of 1896-1905, was a much more critical period. In order to indicate relative severity of the two periods, semi-seasonal yield studies covering the seasons from 1894-95 to 1913-14, inclusive, were made for the more significant combinations of reservoirs. The studies were based upon runoff values listed in Table 13 of Chapter V. If storage capacity had been equal to or less than the estimated 163,000 acre-feet of runoff at Lake Hodges in 1894-95, safe yield during the succeeding drought seasons would have been fixed by storage reserve created in that single season. If storage capacity had been substantially greater than runoff of 1894-95, there would have been carryover storage from the wet season of 1883-84. For the yield studies it was assumed that all reservoirs were full on April 1, 1895.
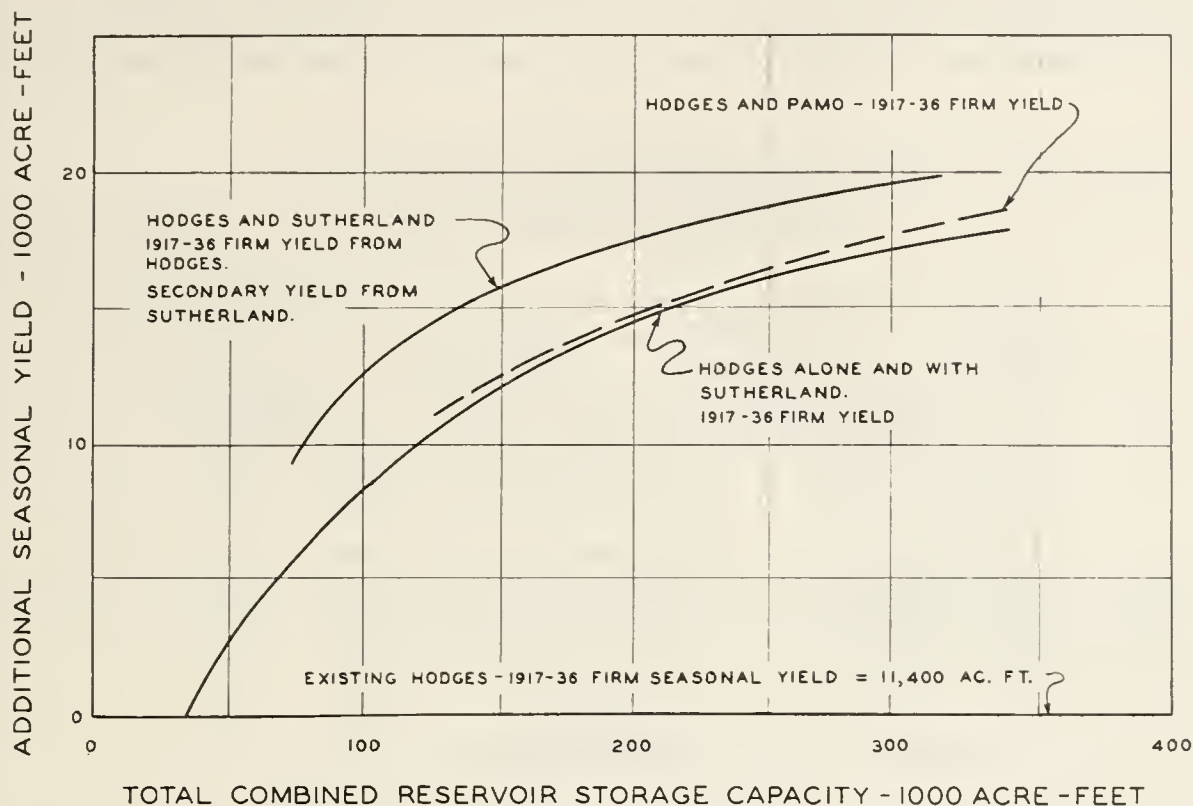
PLATE X

ESTIMATED SEASONAL YIELD
FROM
RESERVOIRS IN SAN DIEGUITO BASIN
1914-15 TO 1944-45, INCLUSIVE

Average seasonal results of semi-seasonal yield studies for the period 1894-95 to 1913-14, inclusive, herein termed "safe yield", are listed in Table 30, which also compares their values with those of corresponding studies for the period 1914-15 to 1944-45, inclusive, herein termed "1917-36 firm yield". It is shown that safe yield during the early period would have varied from 59 to 95 per cent of 1917-36 firm yield of the later period, dependent upon amount and disposition of storage, and method of reservoir operation. While yield studies covering the prior period are not considered as reliable as those for the period following 1914, they are of value in indicating more nearly absolute values of safe yield to be expected from proposed reservoirs in San Dieguito Basin.

TABLE 30

COMPARATIVE VALUES OF 1917-36 FIRM YIELD AND
SAFE YIELD FROM
RESERVOIRS IN SAN DIEGUITO BASIN

Study No.	Storage Capacity in Acre-Feet			1917-36 Firm Yield in Acre-Feet	Safe Yield	
	Hodges	Sutherland	Total		Total	In Per Cent of 1917-36 Firm Yield
A-1	33,600	0	33,600	11,400	6,700	58.8
A-2	104,500	0	104,500	20,200	11,900	58.9
A-3	157,300	0	157,300	24,000	15,600	65.0
A-4	224,800	0	224,800	26,800	20,600	76.8
A-5	338,000	0	338,000	29,400	28,100	95.5
C-1	33,600	36,700	70,300	16,400	9,700	59.1
C-5	301,700	36,700	338,400	29,200	25,100	86.0

In the San Diego region with its characteristic wide seasonal range in runoff, it is essential that a new conservation reservoir be completed well in advance of anticipated need. A number of years may be required for catchment of sufficient runoff to develop required yield. The average period for development of maximum yield will be long when the reservoir's capacity is large as compared with average seasonal runoff, and short when capacity and runoff are more nearly equal. In the case of a large conservation reservoir at Lake Hodges, with storage capacity approximately eight times average seasonal runoff, conservative analysis indicates that construction should precede demands by a period of about ten years. While development of the maximum possible amount of yield might not be attained in this period, sufficient runoff should be accumulated even under adverse conditions to meet the City's initial demands upon this source for supplementary water. There would be a reasonable expectancy that increasing storage and yield would thenceforth keep pace with increasing demands. In the case of Sutherland Reservoir, with storage capacity about 2.4 times average seasonal runoff, the period between completion of construction and initial requirement for water might be much shorter, probably no more than four years, on the average. For other sizes of reservoirs studied at both Pamo and Hodges, the period for development of required initial yield would vary between the foregoing extremes.

Surface Reservoirs

In studies and comparisons of reservoirs at the three principal sites in San

Dieguito Basin, only one location for a dam was considered at each of the Hodges and Sutherland sites. Three possible locations, "A", "B" and "C", were surveyed and examined to a limited degree at Pamo, but studies for this report were based upon an earth-fill type of structure at site "C", furthermost upstream of the Pamo locations.

Sutherland Reservoir

The site of Sutherland Dam is on Santa Ysabel Creek, in the N. W. ¼ of Section 21, T. 12 S., R. 2 E., S.B.B.&M., approximately 6½ miles northeast of Ramona. The reservoir area comprises portions of Sections 20, 21, 22, 27 and 28 in the same township. Streambed elevation of the dam is 1,912 feet.

A topographic survey, and map of the reservoir site to elevation 2,110 feet, at scale of one inch to 300 feet, with contour interval of ten feet, were made for the City of San Diego by Dessery and West, engineers of Los Angeles, in September 1911. Datum of levels of the 1911 survey was approximately 17 feet lower than mean sea level datum of the United States Geological Survey, and indicated elevations were correspondingly high, as is evidenced by corrected tables of capacities placed on the original map by the City in June 1928. A topographic map of the dam site at scale of one inch to 50 feet, with contour interval of two feet, was made by the City of San Diego in August 1927. In making studies and estimates for Sutherland Reservoir in connection with the present investigation, use was also made of cross sections, profiles and structural plans made by the City of San Diego, and by Quinton, Code and Hill, consulting engineers of Los Angeles.

Storage capacities of Sutherland Reservoir at ten-foot intervals of water surface elevation, as computed from areas compiled by the City of San Diego, are given in Table 31.

TABLE 31

AREAS AND CAPACITIES OF
SUTHERLAND RESERVOIR

Depth of Water at Dam in Feet	Water Surface Elevation (U.S.G.S. Datum) in Feet	Water Surface Area[a] in Acres	Capacity[b] in Acre-Feet
0	1,912	0	0
40	1,952	52	728
48	1,960	73	1,227
58	1,970	108	2,124
68	1,980	143	3,377
78	1,990	184	5,004
88	2,000	231	7,073
98	2,010	280	9,624
108	2,020	329	12,663
118	2,030	384	16,230
128	2,040	444	20,378
138	2,050	513	25,145
148	2,060	580	30,618
158	2,070[c]	640	36,724

Notes: a - Data from City of San Diego.
        b - Capacities computed from areas at two-foot
            differences in elevation.
        c - Planned normal water surface with reservoir
            filled.

The electorate of the City of San Diego approved a bond issue on October 19, 1926, to acquire certain riparian rights and to construct Sutherland Dam, Sutherland Aqueduct to the head of San Vicente Creek, San Vicente Dam to a height sufficient for diversion of water to the San Vicente Pipe Line, and the 36-inch diameter San Vicente Pipe Line to Lakeside, to connect there with the El Capitan Line.

Bids were received by the City on January 24, 1927, for construction at the lower Sutherland site of a concrete multiple-arch dam, 161 feet high and approximately 780 feet long. A low bid of $896,742 was received for construction of the dam, outlet works, spillway and 1½ miles of access road. The lower site was subsequently abandoned due to unsatisfactory foundation conditions, and construction of a similar structure was started at a location about 1,000 feet upstream. Construction was finally stopped altogether, after seven buttresses were partly built and a portion of the spillway excavation accomplished.

A structural analysis of plans for the partially completed Sutherland Dam to determine its stability, if completed, was conducted in 1945 by the Supervision of Dams Branch of the Division of Water Resources. The following is quoted from the report on this study:

> "....In making this study numerous plans were examined and an effort made to determine which plans were the proper ones to use. Mr. Verne L. Peugh who was resident engineer during part of the construction, has stated, by letter, he considered the dam was constructed in accordance with the plans made by Quinton, Code and Hill. These plans were not completed in sufficient detail to get all basic data necessary for an analysis and in order to get this necessary information, several other plans were used. It is thought that plans as analyzed reasonably cover the dam as constructed; however, photographs showing the steel projecting out of the upstream face of the haunch does not indicate any uniformity in the amount of steel used. The conclusions of this study are as follows:
>
> 1. The present, partially completed structure, if completed according to the assumed contract plans and specifications, will be a safe structure...."

Prior to resuming construction operations at Sutherland Dam, verification should be obtained that existing work is in accordance with satisfactory plans and specifications.

The upper site at Sutherland, upon which construction was started, was explored by the City of San Diego in the summer of 1927. Seventeen core holes, eleven on the dam axis and six approximately on the alignment of the cutoff wall, were drilled to depths ranging from 40 feet to 110 feet. Data resulting from these corings were assembled on drawing No. N-89 of the City of San Diego, dated September 6, 1927. More complete information relative to subsurface materials resulted from actual construction of foundations for seven buttresses and a portion of the cutoff wall. Foundation material, as indicated by logs of the test holes, consists of hard gneiss, with solid rock near the surface at streambed. The depth of disintegrated and fractured overburden varies from 10 to 30 feet on the right slope, and from 15 to 60 feet on the left slope, as is shown in the bottom of completed portions of the cutoff wall, together with logs of borings.

The structure, as planned for the upper site, layout of which is shown on Plate XI, "Sutherland Dam on Santa Ysabel Creek", consists of 17 reinforced-concrete arch spans, 60 feet from center to center of buttresses, resulting in a total crest length of approximately 1,025 feet. Top of the parapet wall is at elevation 2,074 feet, or 162 feet above

PLATE XI

PLAN

ELEVATION LOOKING UPSTREAM

Crest El 2074

Spillway El 2050

Ground Surface

Gate Hoist
Control Tower

SECTION A-A

SANTA YSABEL

CREEK

Trash Rack

48" Outlet

Crest El 2074

SUTHERLAND DAM
ON
SANTA YSABEL CREEK

SCALE OF FEET

113
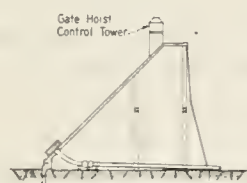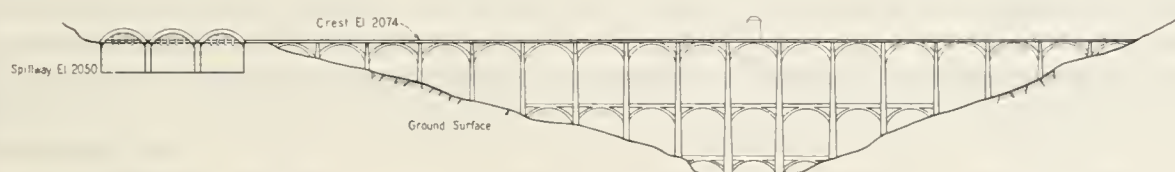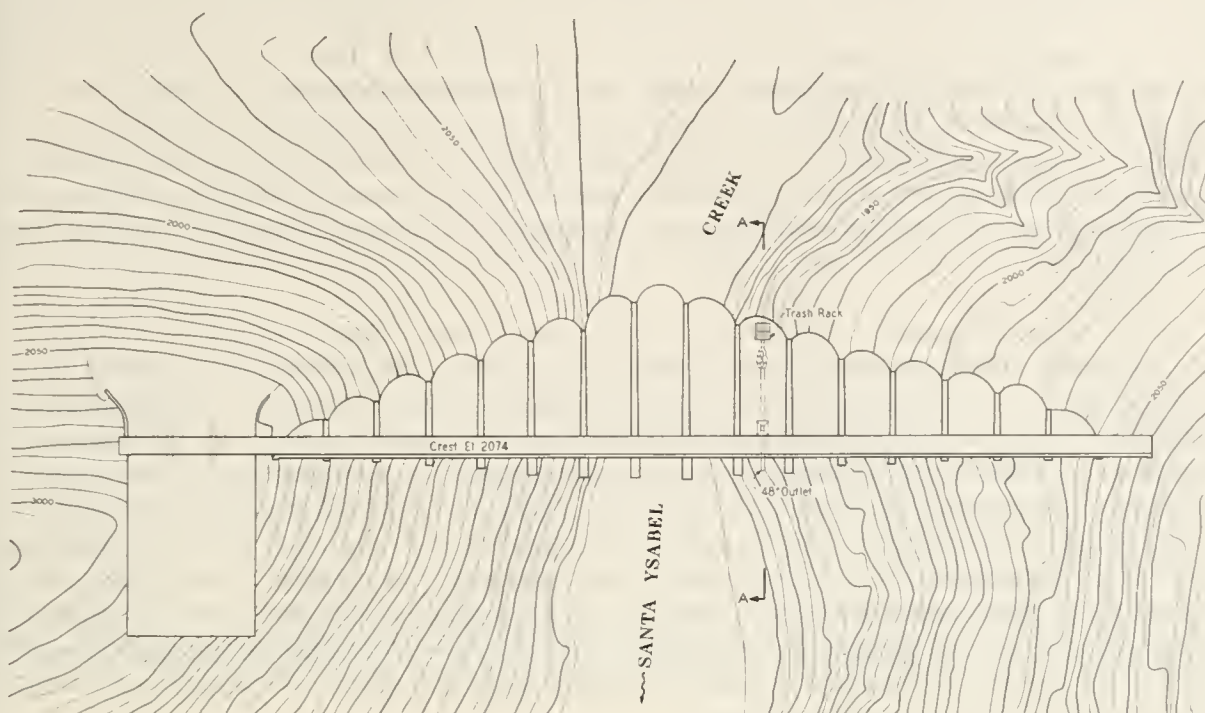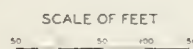
streambed. Normal full reservoir water surface is at the top of drum gates in the spill-
way, at elevation 2,070 feet, at which level storage capacity is 36,724 acre-feet. Fixed
crest of the spillway is at elevation 2,056 feet. Outlet works, as planned by Quinton,
Code and Hill, include a trash rack, and an emergency 5- by 5-foot caterpillar gate on
the inclined face of one arch ring, with the bottom of the opening approximately at ele-
vation 1,950 feet, or 38 feet above streambed. A 48-inch diameter steel pipe with flared
entrance connects the emergency gate with a 48- by 36-inch balanced needle valve, installed
in the 48-inch diameter steel conduit pipe. An alternate arrangement of a double wye and
two 36- by 24-inch balanced valves is also shown on the plans. While estimates for this
report are based on quantities taken from these plans, it is believed that some changes
should be considered in the event of future construction, because of recent knowledge of
cavitation which results from partial gate openings in closed conduits with high head dif-
ferentials.

Crown thickness of the arches varies from 1 foot 6 inches to 5 feet 4 inches,
and the haunch thickness from 2 feet 2 inches to 6 feet. The arches have a central angle
of 140 degrees. Intrados radius is 27 feet for the central 76 degrees, compounded to a
radius of 21 feet 6 inches through 32 degrees of central angle adjacent to the haunches.
The extrados consists of a single arc, with radius varied to accommodate the arch ring
thickness. Reinforced-concrete buttresses are planned, with a thickness of approximately
9 feet 6 inches at streambed level, and 3 feet 4 inches at the top of the dam. Upstream
slope of the buttresses is 1:1, while the downstream edge has a slope of 0.125 down to el-
evation 2,000 feet, below which the slope is 0.40. Lateral stability of the buttresses is
accomplished by arched struts at elevations 1,940 and 2,000 feet, and by bridge arches at
the top of the dam. A reinforced-concrete roadway across the top of the dam is planned,
with a width of 21 feet between curbs.

The spillway, which has been partly excavated, consists of an open cut in the
right abutment, with width of channel between concrete retaining walls of 164 feet. The
spillway control consists of a hollow concrete weir section with three 50- by 14-foot drum
gates. Two concrete piers, 6 feet 8 inches thick, between the gates, support the bridge
over the spillway. Alignment of the bridge is the same as over the dam but on a grade of
three per cent. The plans provide a six-inch concrete apron extending 50 feet upstream
from the weir section, and 12-inch bottom paving between ten-foot high side walls for a dis-
tance of 265 feet downstream. Estimated discharge capacity of the spillway, with reservoir
water surface at elevation 2,073 feet and the gates completely lowered, is approximately
37,000 second-feet. Estimated crest flow of a flood of once in 100-year frequency is
37,300 second-feet, with 65,300 second-feet for a once in 1,000-year flood. It is believed
that the structure will withstand overflow for infrequent short periods without serious
erosion or damage.

Coarse aggregate and a portion of fine aggregate required for concrete were
crushed from stone quarried near the dam site, but in the event of completion of Suther-
land Dam a considerable additional amount of fine aggregate will have to be imported. Cost
estimates for this report assume that all fine aggregate will be imported.

The City of San Diego has acquired title to approximately 1,600 acres of reser-
voir and adjacent marginal lands. It will probably be necessary to acquire an additional
40 acres of privately owned land, together with 40 acres of State land, and to secure flow-
age rights within several parcels of National Forest lands. For purposes of this report,
it is estimated that required additional lands can be acquired for $2,500.

No public roads will be inundated by the reservoir.

Sutherland dam site is accessible by two routes from Ramona. One route comprises a county road extending northeast from Ramona along Rincon Refugio. The alternate road includes approximately 5½ miles of State Route No. 78 and 2½ miles of county and private roads.

Initial plans for development of Sutherland Reservoir included a 36-inch diameter concrete pipe transmission line, approximately 14 miles long, extending southwesterly from the reservoir around the east and south sides of the town of Ramona to Daney Canyon, a tributary of San Vicente Creek. Terminus of the line in Daney Canyon was in Section 33, T. 13 S., R. 1 E., at a point about 6½ miles upstream from San Vicente Dam. A similar conduit, 13.5 miles long, but including one-half mile of tunnel, and with capacity of approximately 45 second-feet, is considered in cost estimates for this report.

Based upon prices prevailing in April 1947, it is estimated that completion of Sutherland Dam, in accordance with the Quinton, Code and Hill plans, will cost $2,342,800, including allowances of ten per cent for administration and engineering, 15 per cent for contingencies, and three per cent interest on capital investment during one-half of the estimated construction period of two years. Annual costs are estimated at $105,500, without consideration of previous capital expenditures at the Sutherland site, but only of those for completion of the dam in its present state. Annual charges include interest at three per cent per annum, amortization over a 50-year period, depreciation of the dam on the basis of 100-year life, and operation and maintenance charges of $10,000. These estimated costs are detailed in Appendix H, "Estimates of Costs".

Estimates of cost for the transmission line from Sutherland Reservoir are based on use of centrifugally-cast, reinforced-concrete pipe, 30 and 36 inches in diameter for gravity and low head portions, and of 36-inch diameter, concrete-cylinder pipe for the higher head portion. With allowances for administration, engineering, contingencies and interest during construction on the same bases as for completion of the dam, estimated April 1947 capital cost of the conduit is $1,334,600. Assuming interest at three per cent per annum, amortization over a 50-year period, depreciation on the basis of 80-year life, and operation and maintenance charges of 0.15 per cent of the capital investment, annual costs are estimated at $58,000. Detailed cost estimates for the conduit are also presented in Appendix H.

In addition to the foregoing studies, a rough cost estimate was made for a rolled earth-fill dam at the present Sutherland site. Estimated cost for this type of structure proved to be greater than that for completion of the multiple-arch dam. Plans for the multiple-arch dam contemplate normal full reservoir water level at the top of raised drum gates, at elevation 2,070 feet. This proposal is considered satisfactory, since failure in gate operation during a flood will result only in overflow of the concrete structure, and it is probable that both dam and foundation rock will withstand infrequent overflow of this type. However, in design of an earth-fill dam, consideration was given to a fixed spillway crest at elevation 2,070 feet, with the top of the fill 20 feet higher at elevation 2,090 feet in order to provide necessary freeboard. In addition to this requirement for a higher dam crest, a greatly increased length of concrete-lined spillway channel would be required for an earth-fill type of dam. These factors account for the conclusion that construction of such a structure would be uneconomic as compared with completion of the multiple-arch dam.

Pamo Reservoir

The three dam sites considered for Pamo Reservoir are located within a one-mile
reach of Santa Ysabel Creek, approximately 1½ miles downstream from its junction with
Temescal Creek, in Section 27, T. 12 S., R. 1 E., S.B.B.&M. Dam site "A" is located near
the west line of Section 27. Site "B" is approximately three-quarters of a mile upstream
from site "A", while site "C" is about 1,700 feet upstream from site "B" and approximately
800 feet west of the east line of Section 27. As a result of considerations hereinafter
discussed, cost estimates of this report are based on an earth-fill dam at site "C".

Surveys and foundation explorations at sites "A" and "B" were begun by the
Volcan Land and Water Company as early as 1913. A number of maps compiled from these sur-
veys were made available by the City of San Diego from its files. More complete and ac-
curate maps of the reservoir and dam sites were made in July 1945 by Fairchild Aerial
Surveys, Inc., in connection with the present investigation. These consisted of the follow-
ing:

    (a) Pamo Reservoir Topography
          scale 1 inch = 400 feet; contour interval, 10 feet; in 2 sheets.
    (b) Pamo Dam Site C
          scale 1 inch = 100 feet; contour interval, 5 feet.
    (c) Pamo Dam Site A
          scale 1 inch = 200 feet; contour interval, 10 feet; (enlarged from
          1 inch = 400 feet reservoir map).
    (d) Pamo Dam Sites B and C
          scale 1 inch = 200 feet; contour interval, 10 feet; (enlarged from
          1 inch = 400 feet reservoir map).

Reservoir areas and capacities above the three dam sites, as determined from the
1945 reservoir map, are given in Table 32 (page 117).

The narrow canyon of Santa Ysabel Creek, in which the three dam sites are situ-
ated, is within an extensive area of granite. At many places old seismic action has frac-
tured and crushed the rock structure, and this, together with weathering, has resulted in
some extensive and deep areas of disintegrated rock. The Volcan Land and Water Company
made core drill borings at both sites "A" and "B", and in addition dug open test pits at
site "B".

Logs of the borings at site "A" were not available for this investigation. How-
ever, site "A" is at the narrowest point in the canyon, and has the best foundation condi-
tions of the three sites. It is believed suitable for a gravity-masonry structure, not ex-
ceeding 200 feet in height. The following is quoted from a letter dated December 2, 1945,
by Chester Marliave, consulting geologist, following his brief visual inspection of the
site:

    "Location A-A at the downstream site offers possibilities for a concrete
gravity type of dam having a height of about 200 feet with crest at elevation
1,000. The right abutment is fairly substantial. The channel section shows
bedrock in blocky outcrops almost entirely across the channel. An overpour
spillway could be used here. Location A-A is also adaptable for an earth dam
having a crest elevation of about 1,000 feet. The right abutment ridge could
be used for the spillway location and only a concrete lining over the ridge at
the end of the dam would be required. The ravine below it would serve as a
wasteway and not have to be lined. For a higher dam at this location, with
crest at about elevation 1,100, the right end should be moved upstream placing
the axis at the location A-A'. For this height of dam an earth dam seems to
be the most feasible type both from a geologic and topographic point of view.
Because of the good alignment of the wasteway ravine on the right abutment of
this side appears to be more favorable than the left side for the location of
the spillway. A cut and cover outlet could be satisfactorily constructed along
the left side of the channel section."

TABLE 32

AREAS AND CAPACITIES OF
PAMO RESERVOIR

Elevation (U.S.G.S. Datum) in Feet	Dam Site "A"		Dam Site "B"		Dam Site "C"	
	Water Surface Area in Acres	Capacity in Acre-Feet	Water Surface Area in Acres	Capacity in Acre-Feat	Water Surface Area in Acres	Capacity in Acre-Feat
805	0	0				
810	0	1				
820	1	8				
830	4	33				
840	10	102				
850	17	236	1	3		
860	27	455	5	30	1	1
870	42	799	15	132	6	36
880	65	1,334	34	376	20	169
890	117	2,244	80	944	64	591
900	156	3,610	115	1,917	96	1,389
910	229	5,535	182	3,400	161	2,672
920	285	8,101	233	5,477	209	4,521
930	347	11,259	290	8,095	264	6,886
940	413	15,057	351	11,302	322	9,815
950	492	19,580	425	15,183	393	13,391
960	581	24,947	509	19,856	475	17,736
970	670	31,206	593	25,370	556	22,895
980	769	38,402	687	31,769	647	28,915
990	868	46,586	781	39,105	739	35,848
1,000	981	55,833	889	47,452	845	43,769
1,010	1,147	66,475	1,050	57,147	1,004	53,013
1,020	1,287	78,647	1,186	68,326	1,138	63,720
1,030	1,428	92,224	1,322	80,866	1,272	75,768
1,040	1,579	107,261	1,469	94,819	1,417	89,212
1,050	1,735	123,832	1,619	110,258	1,565	104,120
1,060	1,920	142,107	1,800	127,354	1,744	120,664
1,070	2,081	162,110	1,956	146,133	1,898	138,871
1,080	2,249	183,760	2,120	166,511	2,060	158,657
1,090	2,389	206,950	2,255	188,385	2,193	179,921
1,100	2,517	231,478	2,378	211,551	2,314	202,460
1,110	2,640	257,265	2,498	235,933	2,433	226,197
1,120	2,769	284,310	2,623	261,536	2,555	251,136

Thirteen core borings made at site "B" by the Volcan Land and Water Company in 1914 would all be within the area covered by a dam 70 feet in height above streambed. The borings showed solid granite to be 15 feet below streambed, and from 30 to 60 feet below the surface on the right abutment. Solid rock was from five to 40 feet below the surface on the left abutment. The overburden consisted of disintegrated granite. Information secured from test pits dug in 1913 was less extensive than from the borings. One test pit on the right abutment, 150 feet above streambed, was 45 feet deep, all in disintegrated granite. The following is quoted from Chester Marliave's comments on this site:

> "The granite here shows some hard outcrops in the channel section only, but this hard rock may not be continuous. The abutments are decomposed and deeply weathered. An earth type of dam seems to be most suited for this location. A spillway could probably be constructed over either abutment beyond the ends of the dam. An outlet tunnel could well be constructed through the left abutment or placed in cut and cover along the left bank of the channel section."

No exploration has been done at site "C". It is evident that a considerable depth of decomposed rock underlies much of the site, especially the right abutment. The following is quoted from Chester Marliave's comments on site "C":

> "The bedrock over this site appears to be a deeply weethered granite with practically no hard outcrops, except near the crest on the right side. The foundation conditions and topography suggest the desirability of an earth type of dam. For a dam with a crest elevation of 1,100 it seems desirable to curve the right end of the axis so that the dam would follow along the ridge. Here the axis should be so placed that the upstream toe slope would fall along the ravine. The toe slope of the channel section should also follow along the base of the hill where bedrock is exposed. The ridge needs only about four feet of stripping so that the location of the axis is not very important as the ridge is quite sound, and needs only a good layer of impervious material on the upstream side of it. A spillway could be constructed across the right abutment ridge about as indicated upon the map, but it would have to be concrete lined for a considerable distance till clear of the downstream toe of the dam. The channel section at this site is quite wide but it does not show hard block rock outcrops that would necessitate blesting in order to prepare the foundation for the compacted fill. The channel also offers sufficient room for the manipulation of equipment, which is a handicap in narrow sections. This site is nearer the borrow pits for earth material than any of the other sites considered. For the same height of dam this site offers the most reservoir storage. In general, this upper site has many favorable features that suggest it being the most feasible location for a dam to store about 200,000 acre-feat."

A reservoir with storage capacity of 163,000 acre-feet would be required at the Pamo sites to retain combined runoff of the 1914-15 and 1915-16 seasons above the sites, less draft and evaporation. This capacity would necessitate a dam approximately 264 feet high at site "A", or 224 feet high at site "C". From the foregoing preliminary geologic information, it is believed that dams of such heights at any of the Pamo sites should be earth-fill structures. Cost estimates for this report were therefore predicated on rolled earth embankments. Likewise, because of geologic considerations favoring site "C" in the case of a dam to create a large capacity reservoir, estimates of cost were limited to structures at that site. Site "B", probably the least favorable location from the geologic standpoint, was not considered in the estimates. It is shown in the following paragraph that cost of dam structures for comparable reservoirs at sites "A" and "C" would be approximately equal.

Embankment material for any of the three sites would have to come from borrow pits located in the wide canyon area upstream from site "C". Additional haul of approximately one mile between sites "A" and "C" was estimated to cost about $0.08 per cubic yard. A dam to impound 163,000 acre-feet of water at site "A" would require approximately 950,000 cubic yards less borrow than a structure with equal capacity at site "C". However, the

seving in quantity of borrow material would be offset by cost of increased haul, to the extent that cost of embankments for comparable structures at sites "A" and "C" would be approximately equal, if the unit price for borrow material at site "C" were $0.50 per cubic yard.

Cost estimates were made for three sizes of rolled earth-fill dams at site "C", with respective reservoir capacities of 90,000, 135,000 and 163,400 acre-feet. Main physical features of the three sizes of dam considered are listed in Table 33, while Plate XII, "Pamo Dam on Santa Ysabel Creek", shows a typical embankment section. Embankment sections have a 30—foot width of crown, and 3:1 slopes both upstream and downstream. Provision for stone riprap, four feet thick on the upstream face, and two feet thick on the downstream face, is included in the estimates. A cutoff trench ten feet in depth below the general stripping level, and 200 feet wide at elevation 880 feet, tepering to 100 feet at the dam crest, is provided on both abutments.

TABLE 33

PHYSICAL FEATURES OF PAMO DAM
FOR THREE SIZES OF DEVELOPMENT

	Reservoir Capacity in Acre-Feet		
	90,000	135,000	163,400
Elevation of crest of dam, U.S.G.S. datum, in feet	1,061	1,088	1,104
Elevation of crest of spillway, in feet	1,041	1,068	1,084
Height of dam to spillway crest, above streambed, in feet	181	208	224
Length of dam at crest, in feet	1,800	2,060	2,230
Net length of spillway crest, in feet	300	250	200
Capacity of spillway with 5-ft. freeboard, in second-feet	66,000	55,000	44,000
Spillway channel			
Length, in feet	1,300	1,200	1,200
Width of bottom lining, in feet	70	70	75
Height of side lining, in feet	20	20	16
Embankment			
Volume, compacted earth fill, rock fill and riprap, in cubic yards	3,727,000	5,697,000	6,945,000
Upstream slope	3:1	3:1	3:1
Downstream slope	3:1	3:1	3:1
Width of crest, in feet	30	30	30

It is assumed that stripping will reach sufficiently tight material in the chennel below elevation 880 feet so that a cutoff will not be required. Assumed portions of materials removed in connection with contingent work are to be incorporated in the embankment. These more pervious materials will be placed in outer zones of the dam. In stripping the dam abutments, it is assumed that 50 per cent of the material will be hauled directly to the embankment and the remainder wasted, as will be the case with common excavation for the spillway. In stripping the channel at the dam site, 70 per cent of the

material is assumed to be stockpiled for later use, and 30 per cent wasted. All common excavation from strip borrow at the dam, and rock, including disintegrated, from the spillway excavation, will be placed directly into the embankment. It is further assumed that all rock from the diversion tunnel excavation will be stockpiled, while material from common open cut excavation for the diversion tunnel will be wasted. Preliminary examination indicates that a sufficient quantity of suitable impervious material for the main portion of the embankment will be available from borrow pits, conveniently located upstream from site "C". If resultant cost estimates had indicated the Pamo reservoir development to be economically favorable, it was planned to make sufficient explorations to verify availability of these materials.

Spillways present a difficult problem, and one expensive of solution, at all Pamo sites. At site "C", cost of the spillway is 30 per cent of total cost of a 90,000 acre-foot reservoir, and 17 per cent of total cost of one of 163,400 acre-foot capacity. Steeply sloping canyon walls necessitate deep cuts along upper sides of spillways. In addition, it is necessary to set invert grades of spillway channels at relatively low elevations in order to avoid fill across small gullies. High channel velocities dictate the provision of gradual changes in vertical and horizontal alignment, and make necessary a concrete lining for the entire length of channel. Spillway crests are proportioned to pass 25 per cent more than an estimated flood of once in 250-year frequency, with reservoir water surface five feet below the crest of the dam. The flood is routed through each size of reservoir, using an approximated 24-hour hydrograph, with momentary peak equal to 2.8 times the mean 24-hour rate, and with crest of approximately seven hours' duration at the mean 24-hour rate.

The estimates include provision for a concrete-lined spillway channel, with an ogee weir section at the upper end, in the right abutment. A concrete apron 50 feet wide is provided upstream from the gravity ogee weir, and a cutoff structure at the downstream end of the channel. Bottom width of the channel is gradually reduced in the first 400 to 600 feet below the weir. Depth of the channel is kept constant, to allow increased freeboard in lower reaches where velocities exceeding 80 feet per second will be experienced. No special provision for dissipation of high velocity flows is made at the outlet end of the channel. It is reasoned that the deflecting lip and cutoff structure will be ample for this purpose for a long period of time, due to infrequency of spill. If detrimental erosion should occur at any time, necessary corrective measures can then be determined, and placed more economically and effectively than during initial construction.

The estimate for the 90,000 acre-foot reservoir includes no provision for a diversion tunnel. It is believed that embankment for this size of structure, together with the spillway, can be completed in one season, if preceded by adequate preliminary operations, such as stripping, excavation, etc. However, construction of a concrete-lined diversion tunnel, of 18-foot inside diameter, and 1,700 feet in length, is included in estimates for the two larger dams. It is assumed that a sufficient amount of embankment will be placed during the first summer season to form a coffer dam about 90 feet high. This head will result in a tunnel discharge capacity of 12,000 second-feet which, together with 13,000 acre-feet of available storage capacity, will handle a two-day flood of magnitude 25 per cent in excess of that of January 27-28, 1916. This is considered a reasonable risk.

PLATE XII

SANTA 850

YSABEL

1100
1050
1000
950
900

35'

Spillway Crest El 1068'

1050
1000
950
900

1100

Crest El 1088'

CREEK

PLAN

Spillway Crest El 1068'
Crest El 1088'
Ground Surface ------
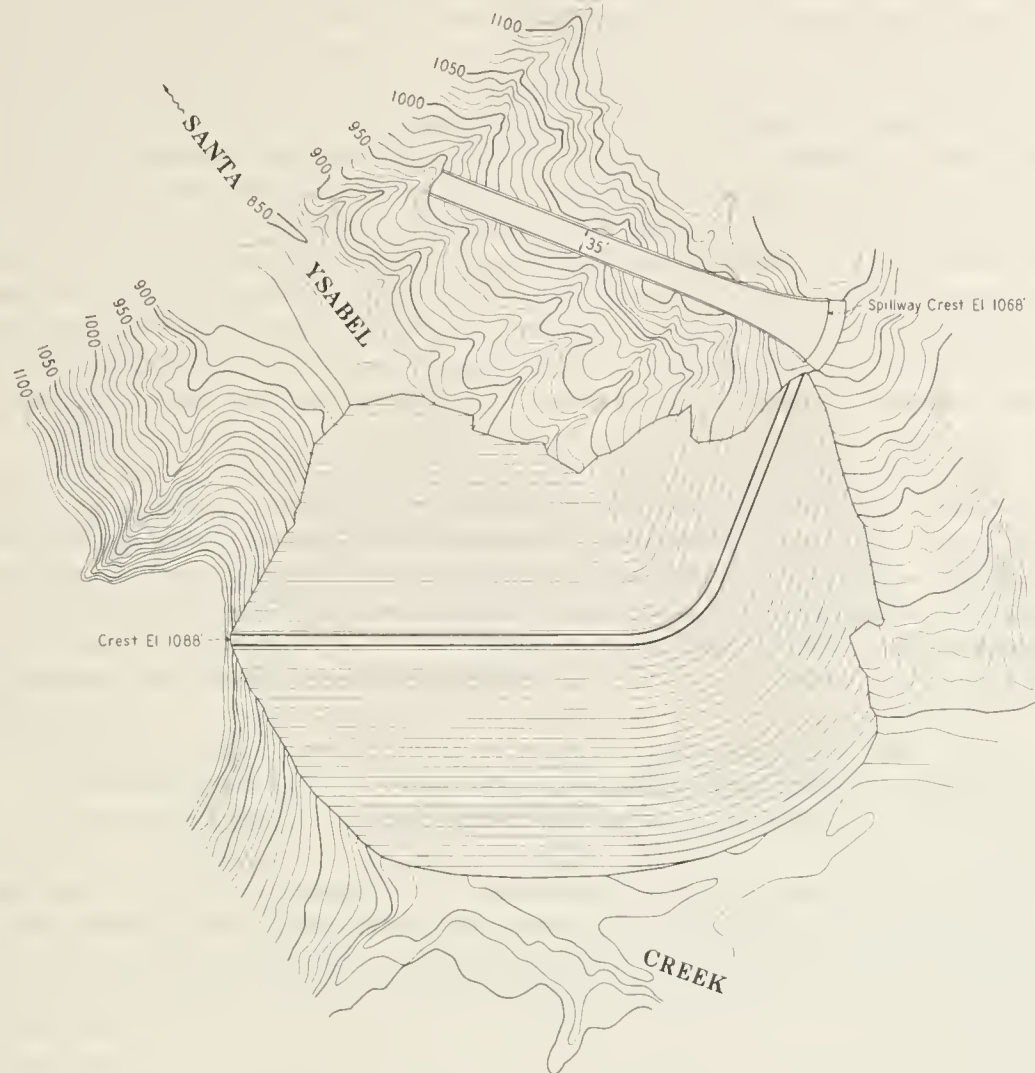
ELEVATION LOOKING UPSTREAM
DEVELOPED PROFILE

1' Rip Rap
10'
2' Rip Rap
3 1
3 1
Impervious
Material
Cut-Off Trench
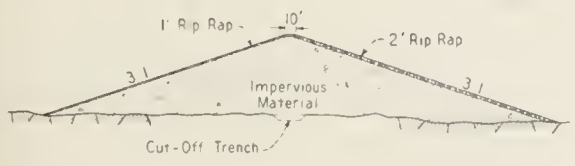
TYPICAL SECTION

PAMO DAM
ON
SANTA YSABEL CREEK
RESERVOIR CAPACITY - 135,000 ACRE-FEET

SCALE OF FEET
100   0   100   200   300

Outlet works include a reinforced-concrete intake tower, at the entrance of a conduit near the upstream toe of the embankment on the left side of the channel. Estimates for the tower are based on the design used at El Capitan Dam on San Diego River. For the 90,000 acre-foot reservoir, the tower is assumed to have an inside diameter of ten feet. Intake is through five 30-inch saucer valves at different levels, the lowest being at elevation 890 feet. Three similar valves are to be located inside the tower at its base, to control flow through the 60-inch diameter concrete conduit. This conduit, 1,300 feet in length, is estimated on the basis of concrete-cylinder pipe with a 15-inch reinforced-concrete encasement, placed in an excavated trench along the toe of the left abutment. Outlet towers for the two larger reservoirs are assumed to be connected to the inlet of the diversion tunnel, which is to be plugged. The towers are 12 feet in inside diameter, and have six 30-inch inlet saucer valves. Outflow is through four 36-inch saucer valves, connecting to 36-inch diameter cast-iron pipes extending through the connecting block and tunnel plug. Estimates for the two larger reservoirs also include provision for two 36-inch diameter welded steel pipes extending to the downstream end of the tunnel.

The City of San Diego has acquired title to approximately 1,160 acres of land comprising portions of Pamo dam and reservoir sites. However, there remains to be acquired areas of 1,320, 1,730 and 1,960 acres of land for the 90,000, 135,000 and 163,400 acre-foot reservoirs, respectively. The bulk of required additional land is located in the narrow valley along Temescal Creek, and some of this area is cultivated. Cost estimates provide for acquisition of 2,483 acres of additional land in the case of each size of reservoir considered. Area required for the smallest reservoir considered includes the better land of affected ownerships, and the access road to Pamo Valley will be inundated. It is therefore concluded that the entire holdings of affected ownerships will have to be acquired. Land prices are estimated by applying a factor of four to the assessed value of unimproved property, and a factor of five to the assessed value of improved property.

No very important public road will be affected by construction of Pamo Reservoir. The principal existing route affected is the county road from Ramona, which enters Pamo Valley just upstream from dam site "C", and extends on to the north about four miles to a ranch at the upper end of the valley. Pamo Ranger Station is located along this road about one mile north of dam site "C", and will be within the flow line of all reservoirs considered. Estimates of this report provide for relocation of 1.0 miles of the connection between the foregoing road and another county road, extending down the Santa Ysabel Canyon past the dam sites. In addition, costs of 0.25 miles of road from a truck trail to connect with the bridge over the dam spillway; 3.6 miles of truck trail relocation around the north end of the reservoir; and 2.25 miles of new road to connect the area near the present Pamo Ranger Station with the Rincon Refugio road, are included in cost estimates.

In order to permit definite comparison between water yield from Sutherland, Pamo and Hodges reservoirs, costs of delivering the water to approximately equivalent points on the existing system of the City of San Diego should be added to reservoir storage costs in each instance. It may be remembered that for Sutherland Reservoir a 13.5-mile gravity pipe line was proposed in order to deliver water to San Vicente Reservoir, where it could be further transmitted through existing pipe lines. The ensuing estimates for both Pamo and Hodges reservoirs include provisions for routing water to a point two miles south and one-half mile east of Hodges Dam, the proposed site of a filtration plant. From this point, at elevation 650 feet, the water is conveyed to Chesterton Tank near the south edge of Linda Vista Mesa, two miles north of San Diego River. Hydraulic gradient at Chesterton

Tank is at elevation 525 feet, and connection can there be made to existing distributing lines and regulating reservoirs on the city system. Detailed economic studies required for final construction planning might result in choice of a lower terminal elevation, with distribution to higher service areas by means of booster pumping plants.

For the gravity conduit from Pamo to the filtration plant, a concrete pipe transmission line, 19.6 miles in length, is included in the estimates. Dependent upon yield of the reservoir under the several studies, pipe line sizes vary from 21 to 42 inches in diameter, and capacities range from eight to 36 second-feet. To determine pipe sizes, a direct release to Santa Ysabel Creek from Pamo Reservoir is assumed, sufficient to provide a seasonal yield at Lake Hodges of 8,200 acre-feet, equal to the total amount of present commitments from the latter reservoir. The amount of this release is subtracted from yield of Pamo Reservoir, and the remainder considered to be conveyed in the pipe line. Pipe line capacities are based on average demand during July. Except for three inverted siphons, the first 12.1 miles of the conduit consist of non-pressure or low-pressure reinforced-concrete pipe. Between mile 12.1 and 12.9 there are 0.8 miles of 6.5-foot diameter, concrete-lined tunnel, and the remaining 6.7 miles of conduit consist of reinforced-concrete, steel-cylinder pipe. The transmission line follows along the left side of Santa Ysabel Canyon to a point about a mile east of the west end of San Pasqual Valley, from whence it turns more to the south through the hills, and crosses U. S. Highway 395 near its junction with Green Valley Road, two miles south of the Bernardo Bridge. It crosses the San Diego Aqueduct one mile east of U. S. Highway 395, at which point its hydraulic grade line is approximately at elevation 780 feet. Hydraulic grade line of the San Diego Aqueduct at this point is at elevation 910 feet.

The conduit from the filtration plant to Chesterton Tank is 16.7 miles in length, and consists of reinforced-concrete-cylinder pipe, with minimum cover of three feet. During periods of maximum flow, head on the conduit will generally be less than 150 feet, but several canyon crossings involve heads exceeding 300 feet. Diameter of the pipe varies with yield under different plans of development, and is chosen so that the hydraulic gradient is at elevation 525 feet at Chesterton Tank. Diameter for high-pressure canyon crossings is assumed as 36 inches in the case of all lines involving pipe of that or greater diameter.

Table 34 (page 124) presents a summary of estimated capital and annual costs of the Pamo Reservoir development, including the transmission conduit, for each of the three sizes studied. The costs are based on prices prevailing in April 1947. Detailed cost estimates for dam and reservoir with storage capacity of 163,400 acre-feet, and for a 39-inch diameter conduit, are presented in Appendix H. Annual charges include interest of three per cent per annum, and amortization over a 50-year period. In the case of the dam and appurtenant structures, depreciation is on the basis of 100-year life, while annual operation and maintenance costs are assumed at $14,500. In the case of the conduit, depreciation is based upon an 80-year life, with annual operation and maintenance costs of 0.10 per cent of the capital investment.

TABLE 34

SUMMARY OF ESTIMATED COSTS OF
PAMO RESERVOIR AND CONDUIT
FOR THREE SIZES OF DEVELOPMENT

(Based upon Prices Prevailing in April 1947)

	Reservoir Capacity in Acre-Feet		
	90,000	135,000	163,400
CAPITAL COSTS			
Dam and reservoir	$5,289,000	$7,893,000	$9,268,400
Conduit	3,876,700	4,079,100	4,256,700
TOTALS	$9,165,700	$11,972,100	$13,525,100
ANNUAL COSTS			
Dam and reservoir	$223,600	$332,100	$389,300
Conduit	166,700	175,400	183,000
TOTALS	$390,300	$507,500	$572,300

Lake Hodgea

The existing Hodges Dam, located in Section 18, T. 13 S., R. 2 W., S.B.B.&M., about 25 miles north of San Diego and seven miles southwest of Escondido, has been described in some datail in an earlier section of this chapter. When full, Lake Hodges covers an area of 1,180 acres, extending about six miles upstream from the dam, with an average width of 0.3 milas. The reservoir is largely contained within the Bernardo Grant.

The Volcan Land and Water Company made a topographic map of the Hodges reservoir area in 1916 at scale of one inch to 400 feet, with contour interval of ten feet to elevation 315 feet, the present normal full reservoir level. The Soil Conservation Service of the United States Department of Agriculture surveyed the reservoir area in July 1935 in connection with silting studies, and prepared a revised map of the same scale and elevation as the earlier one, but with a five-foot contour interval. In July 1945, in connection with the present investigation, Fairchild Aerial Surveys, Inc., made an aerial survey and established surfaca controls, from which that company prepared a topographic map of the reservoir showing a water surface at elevation 312.8 feet, and with ten-foot contours from elevation 320 feet to elevation 400 feet, at scale of one inch to 400 feet. This map, entitled "Super Hodges Reservoir Topography", consists of four sheets, three of topography and one delineating the triangulation system of surface control. The site under consideration for a larger Hodges Dam is located immediately downstream from the present structure. The City of San Diego made a topographic map of this area in 1942, at scale of one inch to 50 feet, with contour interval of five feet to elevation 400 feet. Above this, between elevations 400 and 500 feet, the contour interval is ten feet. In the summer of 1946 the City extended the map 300 feet downstream, below elevation 265 feet, in order to include the site of a possible spillway stilling basin.

Previously accepted reservoir area capacity data were revised for studies of this report, in order to partially account for sedimentation since the original information was compiled. The Soil Conservation Service reported that the July 1935 sedimentation survey of Lake Hodges revealed a 16½-year accumulation of 1,822 acre-feet of sediment, causing a reduction of 120 acres in water surface area at full reservoir stage*. It was also found that 80 per cent of the sediment lay within 25 feet of crest level near the head of the reservoir.

Reservoir capacities from elevation 215 feet to elevation 275 feet, inclusive, presented in Table 35, were computed from water surface areas taken from "Raport on Water Supply for City of San Diego", by H. N. Savage, 1923, based on the Volcan Land and Water Company's 1916 survey. For elevations from 285 to 305 feet, inclusive, areas were also taken from the Savage report, but reduced by the estimated sedimentation. Sedimentation to 1947 was estimated on the basis of results of the 1935 survey. Areas above elevation 305 feet were measured from the contours of the 1945 Fairchild survey.

TABLE 35
AREAS AND CAPACITIES OF
LAKE HODGES

Reservoir Gage Height in Feet	Elevation (U.S.G.S. Datum) in Feet	Water Surface Area in Acres	Capacity in Acre-Feet
0	200	0	0
10	210	0	0
15	215	4	10
25	225	10	81
35	235	26	262
45	245	56	670
55	255	115	1,526
65	265	234	3,270
75	275	351	6,193
85	285	472	10,305
95	295	631	15,820
105	305	886	23,407
112.8	312.8	1,096	31,139
115	315	1,180	33,643
120	320	1,387	40,060
130	330	1,951	56,751
140	340	2,396	78,488
150	350	2,799	104,464
160	360	3,710	137,011
170	370	4,401	177,566
180	380	5,046	224,801
190	390	5,767	278,865
200	400	6,610	340,747

* Technical Bulletin No. 524, "Silting of Reservoirs", United States Department of Agriculture, July 1936, Revised August 1939.

Foundation conditions at the site of Hodges Dam are good. The rock is of mixed origin and very hard. The following comments are taken from "Geologic Report on Lake Hodges Dam", by Chester Marliave, consulting geologist, written in January 1932, in connection with studies made to determine safety of the existing dam during earthquakes:

"The rocks in the vicinity of the dam site are classified as belonging to the 'crystalline complex'. They are the oldest rocks of the region and form the floor upon which the later rocks and sediments rest. They are of pretertiary age, metamorphic in character and composed of a complex mixture of granites, volcanics and altered sediments.

"There is no fault of major activity at the dam site, but a shear zone runs down the canyon and passes through the right abutment of the dam beneath the wasteway section. There is evidence of crushing and indications point to the existence of a fault along this shear zone, but there are no signs of recent movement.

"The channel section of the dam is composed of hard, dense, massive, blocky volcanic rock somewhat basic in character. It is traversed by three systems of fracturing which is prevalent throughout the site. The fractures are tight and allow practically no leakage through the bedrock. It is stated that the buttress excavations were dug to a depth of from 4 to 8 feet where sound rock was encountered.

"The left abutment of the dam is rather steep. The quality of the rock is excellent, being similar to that in the channel section. Fracture planes are prominent in the rock, but appear to be tight with little disintegration along the planes. One large smooth face of rock forms a bluff at the extreme end of the dam. This face represents one of the systems of fracture which is nearly normal to the axis of the dam and is inclined steeply at about 70 degrees toward the river. The fracture planes become tight with increased distance from the surface, and the rock is divided by the fractures into rather large blocks. Very little seepage was observed coming around the abutment of the dam, and there appeared to be no evidence of landsliding or faulting on this side of the canyon. This abutment of the dam is entirely satisfactory.

"The structure of the right abutment is somewhat complex. The basic volcanic rocks are more acid than under the main section of the dam and give way to rhyolitic material at the extreme end of the dam, while in the transition section under the wasteway there are remnants of agglomeratic material. The bedrock, especially under the flat top section of the wasteway, is much softer than that found at other parts of the site. The weakened condition of the rock under the ogee spillway section has been augmented by fault movement along the shear zone but there is no evidence of recent movement along this fault. The flat top section of the wasteway rests upon rocks of softer quality. The extreme end of the section is in contact with rocks of rhyolitic character, but under the central portion of the deck, agglomeratic material is known to exist. As a whole the bedrock under the right abutment of the dam is of satisfactory quality."

During construction of the dam, core borings with a shot drill were attempted, but progress was limited to several inches a day due to hardness of the rock. The shot drill was then replaced with a diamond drill, with which it is known that at least two holes were drilled, one to a depth of 50 feet and the other to a depth of 19 feet. Both holes were in hard rock for almost their entire depth.

A visual examination of the site was made on August 19, 1947, by Elmer C. Marliave, geologist of the Division of Water Resources. The following comments comprise his more important observations:

"The area in the vicinity of the dam site contains a series of old volcanics and sediments that have been intruded by granitic material and have been metamorphosed to varying degrees. No major faults were noted in the area, but shearing and minor faulting are found at many localities. This general area is considered to be seismically active.

"Rocks at the proposed dam site appear to be meta-volcanics, with the more basic rocks in the left abutment and channel sections giving way to a more acid type on the upper right abutment. Considerable of the rock in the present

spillway area is a meta-rhyolite and more of this rock is found at higher elevations, both upstream and downstream from the site. Practically all of the rock, when freshly exposed, is hard and durable and capable of carrying the load of the dams being considered.

"All the foundation rock at the site is strongly jointed. Some local crushing and shearing is noted and gougy seams are found in the more weathered upper portions. The most notable set of joints is on the right abutment where a dip of 25 to 40 degrees toward the channel is joined. These joints cut the rock into slabs, five to ten feet in thickness, and produce sliding planes that may require some special consideration. A nearly vertical joint system parallel to the channel is also quite pronounced. There is a set of streamward dipping joints on the left abutment, quite similar in nature to the set on the right abutment. It was observed in the road cuts below the zone of weathering (approximately 30 feet normal to the surface) that the joints were tighter and cleaner and it appears that they could be properly treated by washing and grouting.

"A strong shear zone exists on the right abutment at elevation 325. It strikes approximately N. 72° E. and dips into the abutment approximately 40 degrees. It extends upstream under the existing spillway apron and downstream beyond the limits of the location considered for a future dam. Material in the zone appears to be a soft light colored tuffaceous material and may have developed from crushing of the meta-rhyolite. This material may improve with depth, but it should be considered a zone of weakness and accorded special treatment. This shear zone is about 25 feet in thickness and has been eroded to depths of over 20 feet by water flowing over the existing spillway.

"It is estimated that stripping about 30 feet deep normal to the surface will be necessary over the abutment areas excepting on a portion of the right abutment area where spill from the existing reservoir has partially cleaned the loose and fractured rock. On this latter area, the stripping will be on the order of five to eight feet. It is estimated that the required stripping in the channel will be from five to ten feet below the bottom of the talus and large boulders. A portion of the channel is relatively clean, but there is some talus and material wasted from the previous construction which has a maximum depth of about 12 feet.

"An overpour spillway can be adapted to this site with moderate protection to the rock at the downstream toe of the dam. If infrequent spilling is contemplated, the protection may be a minimum in the original construction with subsequent maintenance as the need is demonstrated.

"The design of the dam should allow for seismic forces."

In studies for this report, cost estimates were made for five sizes of dam at the Hodges site, principal physical characteristics of which are given in Table 36 (page 128). Layout and a typical section are shown on Plate XIII, "Hodges Dam on San Dieguito River". It may be noted that the largest reservoir considered in the estimates is of 340,700 acre-foot capacity, rather than the 338,000 acre-foot capacity indicated by the yield studies as necessary for complete conservation development of San Dieguito Basin solely by enlargement of Lake Hodges. The excess capacity is provided with elevation of spillway crest at 400 feet, U. S. G. S. datum, the nearest even foot to that for the ideal 338,000 acre-foot capacity indicated by yield studies.

The estimates are based on concrete gravity structures, with vertical upstream faces, and a slope of 0.8 horizontal to 1.0 vertical on downstream faces. Intersection of planes of the upstream and downstream faces is 15 feet above the spillway crest in all cases. The dam axis assumed for the estimates is 100 feet downstream from the axis of the present dam at the right abutment, and 155 feet downstream at the left abutment. Width of dam crests is 15 feet, to provide for a single lane roadway, to be carried over the spillway by a reinforced-concrete bridge.

TABLE 36

PHYSICAL FEATURES OF HODGES DAM
FOR FIVE SIZES OF DEVELOPMENT

	Reservoir Capacity in Acre-Feet				
	104,500	157,300	224,800	310,000	340,700
Elevation of crest of dam, U.S.G.S. datum, in feet	368	382	396	410	416
Elevation of crest of spillway, in feet	350	365	380	395	400
Height of dam to spillway crest, above streambed, in feet	150	165	180	195	200
Length of dam at crest, in feet	900	940	970	1,015	1,050
Net length of spillway crest, in feet	400	400	400	400	400
Capacity of spillway, in second-feet	116,000	106,000	97,000	88,000	97,000
Mass concrete in dam, in cubic yards	265,980	315,900	367,900	425,000	445,000

Depth of stripping is assumed to be 30 feet normal to the slope on both right and left abutments, and from 12 to 15 feet in the channel bottom. Allowance is made for the shear zone on the right abutment by assuming an excavation 60 feet in depth below normal foundation level, and 40 feet in width, to be filled with concrete.

An ogee overflow spillway is contemplated, with net length of 400 feet, to be located over the middle section of the dam. A deflecting lip or bucket is provided near the downstream toe, to deflect the high velocity flow into the air. An estimate of cost was also tentatively made for a stilling basin, to dissipate energy of the overflow by a hydraulic jump. However, this proposal was abandoned in view of its relatively high cost, character of foundation rock, and after consideration of the rarity and short duration of spill that would be experienced with larger dams at Lake Hodges. The spillway is divided by training walls into a 200-foot central section, flanked by 100-foot sections on either side. The deflecting lip of the central section is at elevation 230 feet, or 30 feet above streambed, and lips of the two side sections are at elevation 280 feet, to accommodate the sloping canyon walls. No gates or other regulating devices are provided in the spillway. Freeboard, from spillway crest to top of the dam, varies from 16 to 18 feet for the several sizes of dam considered, and is just sufficient to pass an estimated once in 1,000-year flood, of 163,200 second-feet peak flow, without overtopping the structures. An estimated once in 250-year flood, with peak flow of 119,000 second-feet, will pass over the spillways with freeboard of approximately three feet.

The water supply outlet works include a series of dual 36-inch diameter conduits equipped with double disc gate valves, and extending from the upstream face about 20 feet into the dam, to a vertical well of six-foot diameter. The dual outlets are located at three levels about 50 feet apart, with the lowermost pair at elevation 250 feet. Trash racks, semicircular in plan, are provided on the face of the dam at each level. Main outlet conduits consist of two 42-inch diameter, welded steel pipes, extending from the bottom of the vertical well to the downstream face of the dam. Topography of the site and disposition of the spillway favor the right abutment for location of the outlets. In addition to the foregoing, estimates also include provision for an emergency 36-inch diameter, high-pressure outlet near the base of the dam. This outlet is provided with trash racks, 3.5-foot square emergency slide gate, and a 36-inch balanced regulating valve.

PLATE XIII
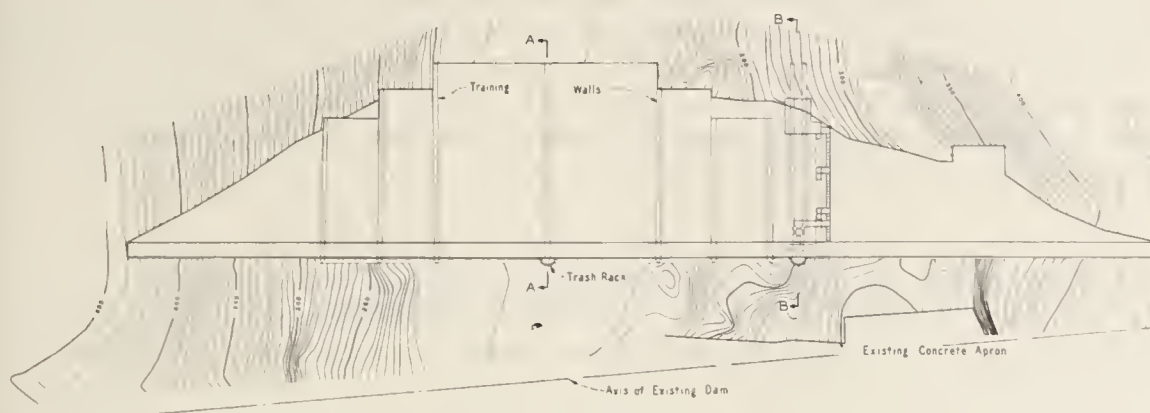
PLAN
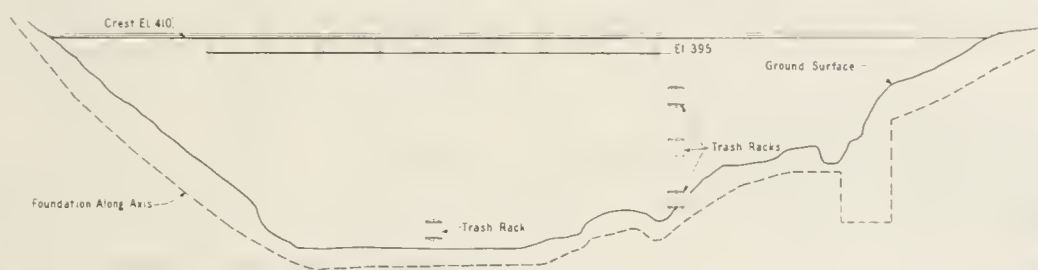
ELEVATION LOOKING DOWNSTREAM

Crest El 410'

El 395

Ground Surface

Trash Racks

Foundation Along Axis

Trash Rack

SECTION A-A

El 410'

Trash Rack

SECTION B-B

Elev 410

Trash Racks

36" dia Outlet Pipe
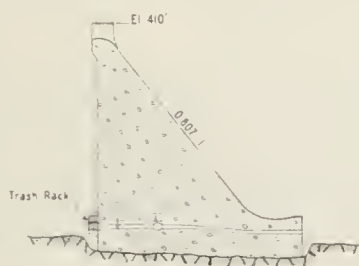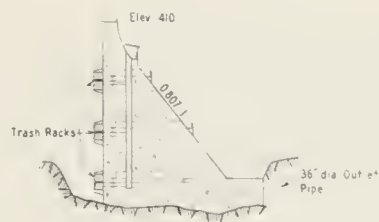
HODGES DAM
ON
SAN DIEGUITO RIVER
RESERVOIR CAPACITY – 310,000 ACRE-FEET

SCALE OF FEET
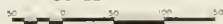
The City of San Diego owns a considerable amount of land within the Hodges reservoir site, much of which extends up to contour elevation 395 feet. Howaver, acquisition of additional land is a major element in estimated cost of Hodges Reservoir, and varies between 17 and 20 per cent of total cost for the several sizes of reservoir studied. Estimates of cost of land acquisition below contour elevations 368, 382, 396 and 416 feet, respectively, were prepared. Two consultants, B. A. Etcheverry and G. F. Mellin, were retained on this work. Table 37 presents a summary of the estimates, based upon their report which is included in Appendix C herein, "Estimates of Cost of Land Acquisition for Lake Hodges and Mission Gorge Reservoirs".

TABLE 37

ESTIMATED COSTS OF REQUIRED ADDITIONAL
RESERVOIR LANDS FOR LAKE HODGES DEVELOPMENT

(Based on 1947 Market Values)

	Elevation of Crest of Dam (U.S.G.S. Datum) in Feet			
	368	382	396	416
Elevation of spillway crest, in feet	350	365	380	400
Reservoir storage capacity, in acre-feet	104,500	157,300	224,800	340,700
Area flooded (excluding presently city-owned land), in acres	717	1,316	2,003	3,216
Area to be acquired (excluding presently city-owned land), in acres	1,222	2,422	4,148	4,871
ESTIMATED COSTS				
Land	$ 381,400	$ 565,200	$ 846,600	$ 904,200
Improvementa	547,000	584,200	753,000	785,700
Damages	96,900	202,700	115,600	120,600
TOTALS	$1,025,300	$1,352,100	$1,715,200	$1,810,500

In preparation of the estimates it was assumed that land would have to be acquired to the elevation of the dam crest, which was considered to be the maximum reservoir flood pool elevation. The estimates are based upon real estate market values as of the spring of 1947. Appraisal of land values was accomplished by applying appropriate factors to 1946 assessed values of the County Assessor, whose information on each property and its improvements was very complete. Factors were determined from an analysis of sales since 1941, for which period due allowances were made in actual sales prices to adjust them to 1947 prices. It was decided to use a factor of five for all farm properties (including lands and improvements), and a factor of six for all subdivision property in Campo Del Dios, as respective ratios of 1947 market values to 1946 assessed values. The estimates include cost of lands and improvements to be purchased, together with accompanying damages, and the cost of relocating affected power and telephone lines. Because the water supply and main pipe line for the Del Dios Subdivision will be flooded with reservoir water surface at elevation 368 feet, it is considered necessary to purchase the entire subdivision in the case of each of the reservoirs studied.

As is shown in Table 37, the relative increment of cost of land acquisition between elevations 396 and 416 feet is considerably less than for lower elevations. This follows partly from the assumption that a large ranch and dairy in San Pasqual Valley can continue to operate if the maximum reservoir water level is kept at elevation 382 feet or lower. For larger reservoirs it is concluded that the entire holdings of this ranch will have to be purchased.

Cost estimates for the several sizes of reservoir include provision for relocation of 9.83 miles of unsurfaced county road, and of 2.14 miles of State Highway No. 78.

Estimates of annual costs of water yielded by Lake Hodges include charges for a pumping plant, and for 2.9 miles of conduit to deliver water to the City's proposed filtration plant site, already mentioned under the discussion of Pamo Reservoir. Also included are costs of 16.7 miles of gravity pipe line to carry the water to Chesterton Tank on Linda Vista Mesa at elevation 525 feet, where it is assumed that connection can be made to the existing city distribution system. The total estimates therefore permit direct comparison between costs of pumped yield from Hodges, and gravity yield from both Pamo and Sutherland reservoirs. In each case, water is delivered to points roughly equivalent as regards elevation, geographic position and relation to existing transmission lines. Treatment plant costs are not included in any of the estimates. As was stated in the discussion of Pamo Reservoir, detailed economic studies required for final construction planning might result in choice of a lower terminal elevation, with distribution to higher service areas by means of booster pumping plants.

The amount of water to be handled by the conduit from Lake Hodges and by the pumping plant is assumed equal to 1917-36 firm yield of the several sizes of reservoir, minus 8,200 acre-feet seasonally which the City of San Diego is committed by contracts to deliver to downstream users, distribution throughout the season being proportional to actual draft by the City and San Dieguito Committees during recent years. It is assumed that the Committees will continue to be served by the existing Hodges Conduit to San Dieguito Reservoir.

The gravity portion of the conduit, from the filtration plant to Chesterton Tank, is similar in characteristics to that described under the discussion of Pamo Reservoir. The conduit from Lake Hodges to the filtration plant consists of 1.0 miles of welded steel pipe, supported above ground by ring girders on concrete piers, and 1.9 miles of concrete-cylinder pipe buried with a minimum cover of three feet. The steel pipe extends downstream along the right bank a distance of about 0.6 miles from the dam, where it crosses the river through an inverted siphon, and continues up a side canyon about 0.4 miles. From this point, concrete-cylinder pipe extends 1.9 miles farther, to relatively flat ground at elevation 650 feet. Size of the pipe line varies with capacity of the reservoir.

Estimates of costs have been made for pumping plants of various capacities, corresponding with yield to the City by five sizes of dam at Lake Hodges, and under three methods of operation. As a basis for estimating, it is assumed that the pumping plant will be located on the right side of the river downstream from the dam and over the

conduit. The plant includes three pumping units of equal size. Installed capacities are based on an assumed minimum reservoir water surface at elevation 225 feet, static lift to elevation 650 feet, plus friction head in 2.9 miles of pipe, overall plant efficiency of 70 per cent, and installed capacity sufficient for 125 per cent of average rate of water demand in July. Energy cost is based on lift from the approximate average reservoir water surface elevation during the critical period utilized in yield studies. The price of electrical energy is based on steam generation with oil fuel, under schedule P-2, with the price of oil at $1.45 per barrel.

Estimated capital and annual costs for five sizes of development of Lake Hodges, based upon prices prevailing in April 1947, are summarized in Table 38, including costs of reservoir, diversion conduit and pumping plant. Capital costs include allowances of ten per cent for administration and engineering, 15 per cent on construction items for contingencies, and, in the case of the reservoir, three per cent interest on capital investment during one-half of the estimated construction period of three years. Annual charges include interest at three per cent per annum; amortization over a 50-year period; depreciation on the basis of lives varying from 100 years in the case of the dam, to 80 years for the conduit, to 50 years in the cases of dam outlet works and pumping plant; and estimated operation and maintenance costs. Annual costs of the pumping plant also include estimated electrical energy and power demand charges. However, they do not include costs of funding such energy and demand charges in perpetuity beyond the end of the amortization period.

TABLE 38

SUMMARY OF ESTIMATED COSTS OF LAKE HODGES
RESERVOIR, CONDUIT AND PUMPING PLANT
FOR FIVE SIZES OF DEVELOPMENT

(Based upon Prices Prevailing in April 1947)

	Reservoir Capacity in Acre-Feet				
	104,500	157,300	224,800	310,000	340,700
CAPITAL COSTS					
Dam and reservoir	$5,965,100	$7,139,500	$8,373,100	$9,432,000	$9,785,200
Conduit					
Dam to filtration plant	263,800	346,500	435,100	435,100	435,100
Filtration plant to Chesterton Tank	1,770,000	1,972,400	1,972,400	2,368,100	2,368,100
Pumping plant	117,800	129,800	138,200	145,000	146,500
TOTALS	$8,116,700	$9,588,200	$10,918,800	$12,380,200	$12,734,900
ANNUAL COSTS					
Dam and reservoir	$250,800	$299,100	$349,300	$393,200	$408,000
Conduit					
Dam to filtration plant	12,200	16,100	20,300	20,300	20,300
Filtration plant to Chesterton Tank	76,100	84,800	84,800	101,800	101,800
Pumping plant	74,100	90,100	100,000	104,900	105,900
TOTALS	$413,200	$490,100	$554,400	$620,200	$636,000

A detailed cost estimate for Lake Hodges with storage capacity of 310,000 acre-feet is presented in Appendix H to serve as an example and indicate unit costs utilized in similar estimates summarized in Table 38. Costs of pumping water from Lake Hodges to the point $2\frac{1}{4}$ miles southeast of Hodges Dam, at elevation 650 feet, are likewise given in Appendix H, under a number of different reservoir storage combinations and assumed methods of operation. A detailed cost estimate of a 36-inch diameter conduit from the filtration plant to Chesterton Tank is presented in the cost estimate in Appendix H for the proposed Pamo reservoir development. Equivalent conduits for Lake Hodges would have similar characteristics, but sizes and costs would vary with the several sizes of proposed development.

Comparison of Surface Reservoirs

In selection of sites and capacities for reservoirs to be included in a program for further conservation development in San Dieguito Basin, much weight should be given to the amount of supplemental yield to be derived therefrom. Water resources of the San Diego region are so limited that a development resulting in lowest unit cost of additional yield might not prove to be the most desirable, unless it also fitted into a plan that would produce an amount of yield near the maximum possible of attainment. It follows that a primary condition in comparison of different reservoirs is that any unit adopted should fit into a plan for complete development of the basin. Complete development should be such as to give maximum supplemental yield over that of the existing development, and at reasonably low unit costs for the water.

For purposes of this report, complete development of San Dieguito Basin is arbitrarily defined as the provision of sufficient storage capacity to conserve the entire runoff of the season of 1915-16. Economic comparisons of reservoirs are made on the basis of unit costs of additional yield to be derived from their construction, above that from the existing development. Seasonal yields from Sutherland, Pamo and Hodges reservoirs, under various combinations of storage capacity and method of operation, were listed in Table 29, values for which were determined for the period since October 1, 1914.

Estimated capital and annual costs for the reservoirs, as given in earlier detailed discussions, are primarily intended to serve as bases for comparison of the several proposals, rather than to constitute exact statements of financial outlays involved. Since cost estimates for each of the several reservoirs are derived on an equivalent basis, the following economic comparisons will not be greatly affected by any general variation in construction costs.

First step in comparison of reservoirs is to establish minimum storage capacity required at Lake Hodges under any combination of reservoirs to effect complete development of San Dieguito Basin. In an earlier discussion in this chapter this was stated to be 174,400 acre-feet, and was determined as the capacity necessary to retain combined runoff of the 1914-15 and 1915-16 seasons from the watershed between Pamo and Hodges dam sites. Lake Hodges, with capacity of 174,400 acre-feet, operated only with runoff below Pamo dam site, would have had a 1917-36 firm seasonal yield of 8,800 acre-feet, and would have spilled in 1941, 1942 and 1943. Storage capacity of approximately 205,000 acre-feet would have been required to avoid all spill in these latter years.

Data pertaining to yield, and to capital and annual costs of Sutherland, Pamo and Hodges reservoirs, have been assembled in Table 39 (page 134), to afford ready comparison of the different reservoirs under various plans of development.

TABLE 39

COMPARISON OF RESERVOIRS IN SAN DIEGUITO BASIN

(Based upon Prices Prevailing in April 1947)

Study No.	Reservoir	Storage Capacity in Acre-Feet	Additional 1917-36 Firm Yield Above that of Existing Development in Acre-Feet per Year	Capital Costs			Annual Costs		
				Total	Storage per Acre-Foot	Additional 1917-36 Firm Yield per Acre-Foot per Year	Total	Additional 1917-36 Firm Yield per Acre-Foot per Year	Increment of 1917-36 Firm Yield from Increase in Storage per Acre-Foot per Year
A.	**OPERATED INDIVIDUALLY**								
C-1	Sutherland	36,700	5,000	$ 3,677,400	$63.83	$ 735	$163,500	$ 32.71	
D-1	Sutherland[a]	36,700	(9,300)[a]	3,677,400	63.83	(395)[a]	163,500	(17.58)[a]	
B-1	Pamo	90,000	11,100	9,165,700	58.77	826	390,300	35.16	)$50.94
B-2	Pamo	135,000	13,400	11,972,100	58.47	893	507,500	37.87	) 58.95
B-3	Pamo	163,400	14,500	13,525,100	56.72	933	572,300	39.47	)
A-2	Hodges	104,500	8,800	8,116,700	57.08	922	413,200	46.95	) 20.24
A-3	Hodges	157,300	12,600	9,588,200	45.39	761	490,100	38.90	) 22.96
A-4	Hodges	224,800	15,400	10,918,800	37.25	709	554,400	36.00	) 31.35
A-6	Hodges	310,000	17,500	12,380,200	30.43	707	620,200	35.44	) 31.50
A-5	Hodges	340,700	18,000	12,734,900	28.72	707	636,000	35.33	)
B.	**OPERATED COORDINATELY FOR COMPLETE DEVELOPMENT**								
C-5	Sutherland	36,700	9,800	$ 3,677,400	$63.83		$163,500		
	Hodges	301,700	8,000	11,318,300	30.99		549,100		
	Totals	338,400	17,800	$14,995,700	$34.58	$ 842	$712,600	$ 40.04	
C-6	Sutherland	36,700	9,800	3,677,400	63.83		163,500		
	Hodges	310,000	8,000	11,390,300	30.42		552,300		
	Totals	346,700	17,800	$15,067,700	$33.96	$ 846	$715,800	$ 40.22	
C-7[c]	Sutherland	36,700	9,800						
	Hodges	310,000	8,000						
	Totals	346,700	17,800						
Costs under plan of study No. C-6				15,067,700	33.96	846	715,800	40.22	
Savings from ten-year delay in enlargement of Lake Hodges				4,169,300	12.02	234	173,800	9.77	
	Adjusted Costs			$10,898,400	$21.94	$ 612	$542,000	$ 30.45	
D-8	Sutherland[a]	36,700	(14,100)[a]	3,677,400	63.83		163,500		
	Hodges	277,800	5,800	10,994,100	32.67		510,900		
	Totals	314,500	19,900	$14,671,500	$36.32	$(737)[a]	$674,400	$(33.89)[a]	
B-4	Pamo	163,400	21,400	14,137,900	56.72		598,600		
	Hodges	174,400	-2,600	7,480,000	42.89		313,000		
	Totals	337,800	18,800	$21,617,900	$49.58	$1,150	$911,600	$ 48.49	
G-1	Sutherland	36,700	9,700	3,677,400	63.83		163,500		
	Pamo	127,800	11,700	10,999,100	58.61		470,900		
	Hodges	174,400	-2,600	7,480,000	42.89		313,000		
	Totals	338,900	18,800	$22,156,500	$51.09	$1,179	$947,400	$ 50.40	
C.	**OPERATED COORDINATELY FOR PARTIAL DEVELOPMENT**								
E-1	Sutherland[a]	36,700	(14,100)[a]	$ 3,677,400			$163,500		
	Pamo	90,000	8,200	7,715,300			327,900		
	Hodges[d]	33,600	-6,900	0			0		
	Totals	160,300	15,400	$11,392,700	$47.61	$(740)[a]	$491,400	$(31.91)[a]	
P-1	Sutherland	36,700	9,800	3,677,400			163,500		
	Pamo	127,800	11,100	10,384,700			444,500		
	Hodges[d]	33,600	-6,900	0			0		
	Totals	198,100	14,000	$14,062,100	$49.64	$1,004	$608,000	$ 43.43	

Notes: a - Sutherland Reservoir operated for secondary yield, rather than 1917-36 firm yield.
b - Estimated from curves.
c - Identical with study No. C-6, but with costs reduced by savings resultant from ten-year delay in enlargement of Lake Hodges, as compared with costs if initial development had been under plan of study No. A-5.
d - Existing Lake Hodges.

Reservoirs Operated Individually

The data under heading "A" of Table 39 are based on assumed individual operation of the several reservoirs for maximum 1917-36 firm yield. In the cases of Sutherland and Pamo reservoirs, of course, such operation is in conjunction with the existing Lake Hodges. It may be noted from these comparisons that development of Lake Hodges stands out most favorably as regards unit costs for larger increments of 1917-36 firm yield. However, if Sutherland Reservoir is operated for secondary water, as shown in study No. D-1, an additional average seasonal yield of 9,300 acre-feet of such water is realized, at relatively low unit cost. No attempt has been made to relate the value to the City of San Diego of such secondary water, as compared with that of 1917-36 firm yield.

Reservoirs Operated Coordinately for Complete Development.

From inspection of unit costs of additional 1917-36 firm yield listed under heading "A" of Table 39, it appears that no combination of reservoirs for complete development results in lower unit costs than can be attained by operating Lake Hodges alone, with the possible exception involving operation of Sutherland Reservoir for secondary water, in conjunction with operation of Lake Hodges on a 1917-36 firm yield basis. However, a comparison of several plans for complete development, including either Sutherland or Pamo reservoirs, or both, operated coordinately with Lake Hodges, is given under heading "B" of Table 39.

Unit costs of combined additional 1917-36 firm yield from reservoirs at both Pamo and Hodges are greater than those for any reservoir at Hodges alone, having capacity greater than 174,400 acre-feet. If complete development of San Dieguito Basin is accomplished by providing storage of 174,400 acre-feet at Lake Hodges, and the remaining 163,400 acre-feet at Pamo, as shown in study No. B-4, resulting additional 1917-36 firm seasonal yield of 18,800 acre-feet probably constitutes the highest possible ratio of such yield to storage capacity. However, unit cost of the additional yield is $48.49 per acre-foot, as compared with $35.33 per acre-foot in study No. A-5, for complete development at Lake Hodges alone. For any development that will conserve the runoff originating between Pamo and Hodges, including as it must increased capacity at Lake Hodges, costs of remaining storage capacity at Pamo required for complete development of San Dieguito Basin are several times as great as those for equivalent capacity at Hodges, if the latter capacity is provided in the initial development.

It may be noted that study No. B-4 shows additional 1917-36 firm yield from Lake Hodges to be a negative quantity. This is explained by the fact that large upstream storage will conserve much runoff presently reaching Lake Hodges. While enlargement of Lake Hodges is necessary even under such circumstances, to completely conserve runoff originating below Pamo Reservoir, the yield to be realized from the enlarged Lake Hodges is less than that of the existing development. Total yield from the combined development of study No. B-4 is much greater, of course, than under present conditions. Similar considerations account for negative additional 1917-36 firm yield from Lake Hodges, noted in studies Nos. G-1, E-1 and F-1.

Studies of coordinated operation of reservoirs at Sutherland and Hodges were made, with Sutherland operated both for 1917-36 firm yield and for secondary water with maximum diversion rate of 42.4 second-feet. A reservoir of 36,700 acre-foot capacity was the only one considered at Sutherland, the capacity if the dam is completed in accordance with original plans. If operated for 1917-36 firm yield from Sutherland, 301,700 acre-feet of storage

capacity is required at Lake Hodges to effect complete basin development. This, as is shown in study No. C-5 of Table 39, results in additional 1917-36 firm seasonal yield of 17,800 acre-feet at unit cost of $40.04 per acre-foot. This figure may be compared with that for complete development by means of Lake Hodges alone, which provides approximately the same amount of additional 1917-36 firm yield, at unit cost of $35.33 per acre-foot.

If complete basin development is achieved by the foregoing Sutherland-Hodges combination, but with enlargement of Lake Hodges deferred after construction of Sutherland Reservoir until required by increased water demand, the comparative cost advantage of complete development at Lake Hodges alone is reversed. It is considered conservative to take this period of delay as ten years, particularly in view of the fact that other factors, such as construction of the second barrel of the San Diego Aqueduct, may defer construction of an enlarged Lake Hodges for a much longer period. Savings in annual costs by construction of Sutherland Reservoir, as shown in study No. C-1 of Table 39, rather than initial enlargement of Lake Hodges to the size required for complete basin development demonstrated by study No. A-5, amount to approximately $4,169,000 in a period of ten years. These savings consist of charges for interest on and amortization of the capital investment in reservoir, conduit and pumping plant; depreciation of the physical works; and operation and maintenance, including power costs for pumping. If costs of Lake Hodges are credited on the basis of these savings, resultant unit cost of additional 1917-36 firm yield from the Sutherland-Hodges combination for complete basin development is $30.45 per acre-foot, as is shown in study No. C-7.

If Sutherland Reservoir is operated for secondary water, the seasonal diversions vary from 1,150 to 30,710 acre-feet and average 14,100 acre-feet. Under such circumstances, storage capacity of 277,800 acre-feet at Lake Hodges effects complete development of the basin, and 1917-36 firm seasonal yield of 17,200 acre-feet is realized from Lake Hodges alone. This is shown in study No. D-8 of Table 39. Total average seasonal yield under this plan, including secondary water, amounts to 31,300 acre-feet, a figure 19,900 acre-feet in excess of that of the existing development. Unit cost of the additional yield is $33.89 per acre-foot.

Under the combination demonstrated in study No. G-1 of Table 39, Lake Hodges is constructed to a capacity of 174,400 acre-feet. Sutherland Reservoir is completed to its planned capacity of 36,700 acre-feet, and remaining storage necessary to effect complete basin development is furnished by 127,800 acre-feet at Pamo. Combined capacity amounts to 338,900 acre-feet and resultant additional 1917-36 firm seasonal yield is 18,800 acre-feet at unit cost of $50.40.

Reservoirs Operated Coordinately for Partial Development
Results of two studies for coordinated operation of Sutherland, Pamo and Hodges reservoirs under partial development of the basin are given under heading "C" of Table 39. Assumed storage capacity of Sutherland Reservoir is 36,700 acre-feet, while storage capacities of Pamo Reservoir are taken at 90,000 acre-feet and 127,800 acre-feet, respectively.

In study No. E-1, Sutherland Reservoir is considered to be operated for secondary water, while the 90,000 acre-feet of storage at Pamo is operated on a 1917-36 firm yield basis. Secondary yield from Sutherland averages 14,100 acre-feet per season, while 1917-36 firm seasonal yield from Pamo is 8,200 acre-feet. However, 1917-36 firm yield of the existing Lake Hodges is reduced from 11,400 acre-feet to 4,500 acre-feet, seasonally.

Average additional seasonal yield for the entire development is 15,400 acre-feet, at unit cost of $31.91 per acre-foot.

In study No. F-1, all reservoirs are operated on a 1917-36 firm yield basis, and complete development of the basin above Pamo is attained by assuming storage capacity of 127,800 acre-feet at Pamo Reservoir. Combined storage capacity is 198,100 acre-feet, which results in additional 1917-36 firm seasonal yield of 14,000 acre-feet, at unit cost of $43.43 per acre-foot.

Sutherland and Hodges Reservoirs Operated Coordinately

In order to consider all possibilities for salvaging the past investment in Sutherland Dam, and to seek justification for the additional expense required to complete it, estimates were made of unit costs of combined additional seasonal yield for reservoirs of various capacities at Lake Hodges when operated coordinately with Sutherland Reservoir. Parallel studies were made, involving operation of Sutherland Reservoir for both secondary water and for 1917-36 firm yield. The results are given in Table 40, and shown graphically on Plate XIV, "Costs of Additional Seasonal Yield from Reservoirs in San Dieguito Basin".

TABLE 40

COMPARISON OF PLANS FOR COORDINATED OPERATION
OF SUTHERLAND AND HODGES RESERVOIRS

(Based upon Prices Prevailing in April 1947)

Study No.	Method of Operation		Storage Capacity in Acre-Feet			Additional Seasonal Yield Above that of Existing Development in Acre-Feet				Capital Costs			Annual Costs	
						1917-36 Firm Yield			Secondary Yield	Total	Storage per Acre-Foot	Additional Yield per Acre-Foot per Year	Total	Additional Yield per Acre-Foot per Year
	Hodges	Sutherland	Hodges	Sutherland	Total	Hodges	Sutherland	Total	Sutherland					
C-1	1917-36 firm yield	1917-36 firm yield	33,600	36,700	70,300	-4,800	9,800	5,000	0	$ 3,677,400	$63.83	$735	$163,500	$32.71
C-2	1917-36 firm yield	1917-36 firm yield	104,500	36,700	141,200	1,700	9,800	11,500	0	11,097,500	58.84	965	510,900	44.43
C-3	1917-36 firm yield	1917-36 firm yield	157,300	36,700	194,000	5,000	9,800	14,800	0	12,531,300	48.88	847	586,900	39.65
C-4	1917-36 firm yield	1917-36 firm yield	224,800	36,700	261,500	6,400	9,800	16,200	0	14,001,900	40.90	864	652,200	40.26
C-5	1917-36 firm yield	1917-36 firm yield	301,700	36,700	338,400	8,000	9,800	17,800	0	14,995,700	34.58	842	712,600	40.04
C-6	1917-36 firm yield	1917-36 firm yield	310,000	36,700	346,700	8,000	9,800	17,800	0	15,067,700	33.96	846	715,800	40.22
D-1	1917-36 firm yield	Secondary yield	33,600	36,700	70,300	-4,800	0	-4,800	14,100	3,677,400	63.83	395	163,500	17.58
D-3	1917-36 firm yield●	Secondary yield●	33,600	36,700	70,300	0	0	0	8,800	3,677,400	63.83	418	163,500	18.58
D-5	1917-36 firm yield	Secondary yield	104,500	36,700	141,200	1,600	0	1,600	14,100	11,095,300	58.84	707	509,600	32.46
D-6	1917-36 firm yield	Secondary yield	157,300	36,700	194,000	3,400	0	3,400	14,100	12,488,900	48.88	714	577,200	32.98
D-7	1917-36 firm yield	Secondary yield	224,800	36,700	261,500	4,800	0	4,800	14,100	13,763,100	40.98	728	633,600	33.53
D-8	1917-36 firm yield	Secondary yield	227,800	36,700	314,500	5,800	0	5,800	14,100	14,671,500	36.32	737	674,400	33.89
D-9	1917-36 firm yield	Secondary yield	310,000	36,700	346,700	5,800	0	5,800	14,100	15,028,400	33.96	755	690,700	34.71

Note: ● - 1,500 acre-feet of dead storage in Lake Hodges. 17,200 acre-feet of reserve storage in Sutherland Reservoir for release to Lake Hodges.

Summary

A brief examination of the foregoing comparisons of reservoirs is sufficient to show that Pamo Reservoir may be eliminated from further consideration at this time, because of high unit cost of additional yield under any plan for complete basin development which includes that reservoir. The possibility remains, however, that Pamo Reservoir may eventually be justified in connection with terminal storage of an imported water supply for the San Diego region. Two general plans are left to be considered for present adoption, the first consisting of enlargement of Lake Hodges alone, and the second involving completion of Sutherland Reservoir to designed capacity, together with enlargement of Lake Hodges. Further examination discloses that the most favorable proposals under the respective general plans are as follows:

    1. Construction of Lake Hodges alone, with storage capacity of 340,700 acre-feet, as described under study No. A-5.

    2. Combined development, including construction of 301,700 acre-feet of storage capacity at Lake Hodges, and 36,700 acre-feet at Sutherland Reservoir, as described under study No. C-5.

Additional 1917-36 firm seasonal yield in the case of either of these developments is approximately 18,000 acre-feet. A summary of studies Nos. A-5 and C-5, together with several related studies, is given in Table 41 for convenient reference. This table also sets up comparisons between the plans on the basis of safe yield during the record drought of 1895-96 to 1904-05, inclusive.

TABLE 41

SUMMARY OF PLANS FOR DEVELOPMENT
OF LAKE HODGES AND SUTHERLAND RESERVOIR

(Based upon Prices Prevailing in April 1947)

Study No.	Storage Capacity in Acre-Feet		Additional Seasonal Yield in Acre-Feet		Costs			
							Additional Yield per Acre-Foot per Year	
	Hodges	Sutherland	1917-36 Firm Yield	Safe Yield	Capital	Annual	1917-36 Firm Yield	Safe Yield
A-5	340,700	0	18,000	21,400	$12,734,900	$636,000	$35.33	$29.72
C-5	301,700	36,700	17,800	18,400	14,995,700	712,600	40.04	38.73
C-6	310,000	36,700	17,800	18,400	15,067,700	715,800	40.22	38.90
C-7*	310,000	36,700	17,800	18,400	10,898,400	542,000	30.45	29.46
C-1	33,600	36,700	5,000	3,000	3,677,400	163,500	32.71	54.50

Note: * - Identical with study No. C-6, but with costs reduced by savings resultant from ten-year delay in enlargement of Lake Hodges, as compared with costs if initial development had been under plan of study No. A-5.

It may be noted from Table 41 that the increment of safe yield to be obtained under the listed plans for complete conservation development of San Dieguito Basin is greater than the corresponding increment of 1917-36 firm yield. This is true because 1917-36 firm yield as related to safe yield is proportionately greater in the case of the small existing Lake Hodges than in the cases of large capacity reservoirs required for complete

PLATE XIV
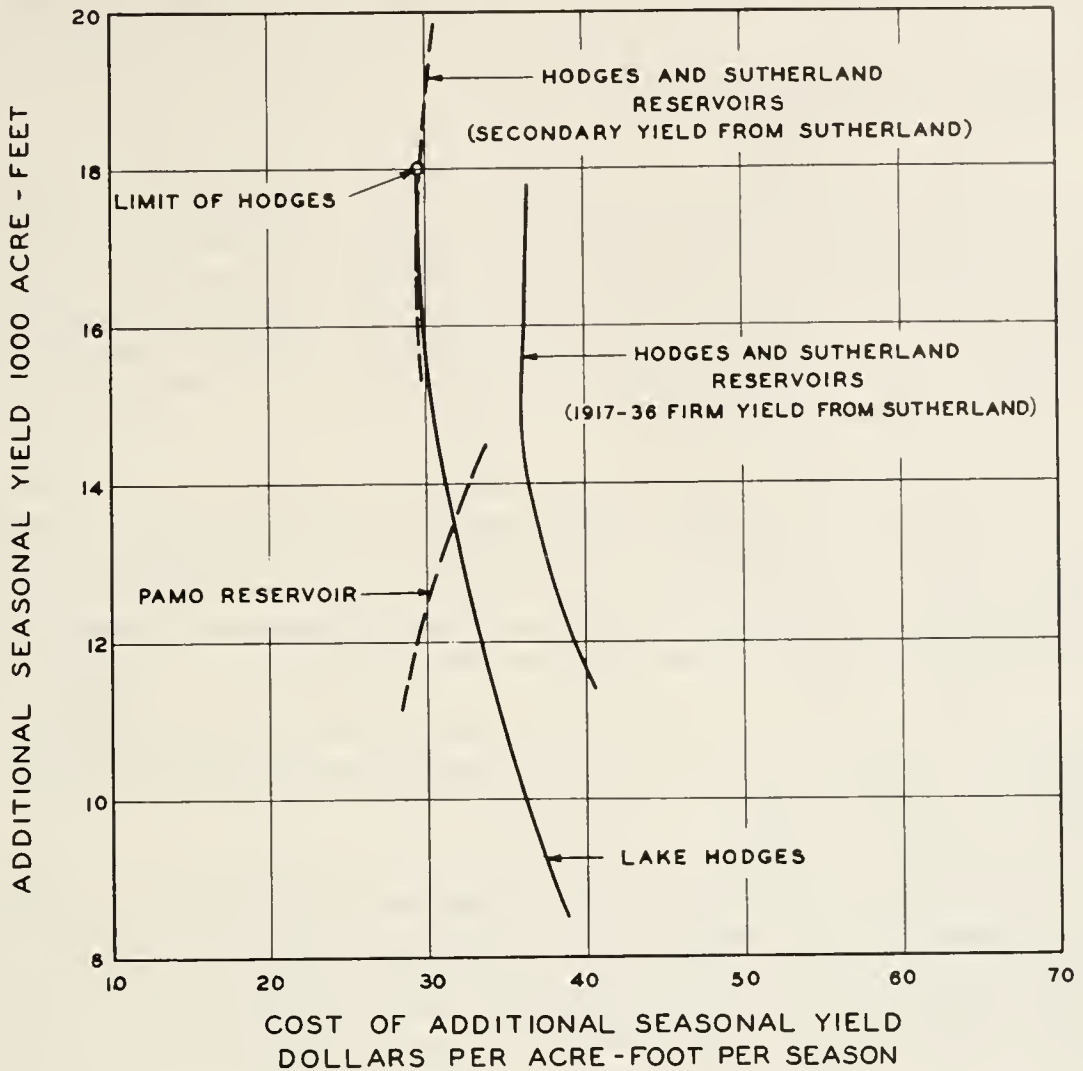
COSTS OF ADDITIONAL SEASONAL YIELD
FROM RESERVOIRS IN SAN DIEGUITO BASIN

conservation development. As an example, under study No. C-5 total 1917-36 firm seasonal yield is increased from 11,400 acre-feet for the present Lake Hodges to 29,200 acre-feet with complete development, an amount of 17,800 acre-feet. However, under the same study, total seasonal safe yield increased correspondingly from 6,700 to 25,100 acre-feet, an amount of 18,400 acre-feet. These considerations account for the greater indicated unit costs of additional 1917-36 firm yield, as compared with corresponding costs for addition-al safe yield, for studies Nos. A-5, C-5, C-6 and C-7.

In finally selecting a plan for complete conservation development of San Die-guito Basin certain practical and intangible factors merit consideration. Estimates pre-sented in Chapter III of this report indicate that the City of San Diego now has a water supply development sufficient to meet its probable demands well beyond the year 1960, if, as is probable, runoff sufficient to re-establish full safe yield of the existing storage system occurs before that date. Based on the necessity of securing additional water the need for full conservation development of San Dieguito Basin is not immediate. However, other factors should be considered.

The City of San Diego has a large investment in reservoir sites in San Dieguito Basin, and has recently made filings to appropriate all excess waters of the river. Value of water in this semi-arid region is so great as to assure further development of this at-tractive source by other agencies, public or private, unless the City takes steps to con-summate these filings. To accomplish this, reasonable diligence must be shown as regards placing the water to beneficial use. While additional San Dieguito Basin water is not im-mediately required by the City, it may be put to beneficial use in lieu of presently pur-chased Colorado River water. A plan permitting accomplishment of full conservation de-velopment of the basin by stages, with initial steps to be taken as soon as possible, will accomplish this desirable end.

Adoption of the plan outlined in study No. C-5 accomplishes such staged develop-ment of the basin, through initial construction of Sutherland Reservoir to a storage capa-city of 36,700 acre-feet, and subsequent enlargement of Lake Hodges to 301,700 acre-foot capacity. However, a very similar plan, No. C-6, provides 310,000 acre-feet of storage at Lake Hodges, and has certain practical advantages. At increased capital cost of only $72,000, additional storage capacity of 8,300 acre-feet is provided. This increment com-pensates for future losses of storage space by silting, and in the meantime provides regu-latory capacity for possible imported water.

In Table 41 estimated unit cost of additional 1917-36 firm seasonal yield under the plan of study No. C-6 is shown to be $40.22 per acre-foot, compared to $35.33 under study No. A-5. However, by rational considerations as to financing, cost of yield under study No. C-6 is reduced if this plan is constructed by stages. From the standpoint of costs, an ideal program of water supply development is one involving a graduated schedule paralleling the increase in demand. On the basis of present trends of population growth and per capita consumption of water, a period of at least ten years will elapse after com-pletion of Sutherland Reservoir before enlargement of Lake Hodges is required. This per-iod may be appreciably increased by other factors, but in ten years the savings in annual costs over those of the plan of study No. A-5 amount to $4,169,000. If this accrued sav-ing is credited to costs of Lake Hodges under the plan of study No. C-6, reduced unit cost of additional 1917-36 firm seasonal yield is $30.45 per acre-foot, as is shown under study No. C-7.

It may be noted that a rise in cost of power for pumping further increases the monetary advantage indicated in study No. C-7 for complete development by staged construction of Sutherland and Hodges reservoirs, rather than by initial enlargement of Lake Hodges. Since the estimates for this report were made, energy costs for required pumping have risen an average of approximately 40 per cent.

Construction of Sutherland Reservoir by itself provides additional 1917-36 firm seasonal yield of 5,000 acre-feet at unit cost of $32.71. If operated for secondary water, average seasonal yield is 8,800 acre-feet at unit cost of $18.58. While these unit costs are less than result from any plan for complete conservation development of the basin, it is believed that any plan for only partial utilization of local water resources is inadvisable in the San Diego region, and that municipal water supply for the City of San Diego should be planned on a firm or safe yield basis. Moreover, the intrinsic value of secondary water is largely indeterminate, dependent as it is upon ability of the City to utilize the water approximately at the time of its occurrence.

Several additional factors tend to favor a plan including Sutherland Reservoir. The existence of this reservoir will provide the City with greater flexibility of operation between its several major systems, and a higher diversion level and gravity delivery for a portion of the additional yield. With this plan completed, 9,800 acre-feet, or 55 per cent of the additional 1917-36 firm seasonal yield, can be diverted from Sutherland Reservoir to the San Diego River system by gravity. On the other hand, with a plan including Lake Hodges alone, the entire amount of additional yield must be lifted an average height of approximately 300 feet.

Yield from Underground Reservoirs

The only underground water basins within the San Dieguito watershed of sufficient size to warrant consideration in connection with further conservation development are those underlying the San Dieguito and San Pasqual valleys. Any appreciable additional yield of water from San Dieguito Basin must necessarily come about through salvage of flood waters now wasting into the ocean or in reduction in natural consumptive use. To this end, the possibility of utilizing underground reservoirs for seasonal and cyclic storage of flood waters should be considered, as well as any possibility of their use for conserving water presently utilized by consumptive use of natural vegetation.

Seasonal and Cyclic Storage

In 1919[*] Charles H. Lee estimated that effective area of the ground-water basin underlying San Dieguito Valley was 1,220 acres, and that the water table could be practicably lowered an average depth of 30 feet. With estimated specific yield of 20 per cent, utilizable storage capacity of the underground reservoir was therefore 7,300 acre-feet. A review by J. C. Kimble, Jr., engineer-geologist of the Division of Water Resources, in 1934, confirmed results of Lee's earlier studies. In estimating yield, Lee arrived at an annual amount of 2,430 acre-feet, based on the assumption that after three years of drought, accumulated draft from the ground water would be completely replenished by surface runoff in the fourth year.

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[*] Water Supply Paper 446, "Geology and Ground Waters of the Western Part of San Diego County, California", U. S. Geological Survey, 1919.

The assumption that replenishment of the ground-water basin would be accomplished in the fourth year in a drought period will not be true if Lake Hodges is constructed to the capacity required for complete basin development under coordinated operation with Sutherland Reservoir. A reservoir of such capacity will spill only at rare intervals, and replenishment from the drainage area below Hodges Dam will be very slow. Furthermore, the low elevation of the San Dieguito Valley will prevent appreciable lowering of the water table, especially at the lower end of the valley, because of the menace of infiltration of sea water. For these reasons, it is believed that development of the underground water basin in San Dieguito Valley is not sufficiently attractive to warrant further consideration, except by overlying land owners.

Charles H. Lee in 1919 estimated that utilizable storage capacity of the San Pasqual Valley ground-water basin was 13,200 acre-feet. J. C. Kimble, Jr., in his 1934 review arrived at the same capacity.

A reservoir at Lake Hodges, having capacity sufficient for complete basin development under coordinated operation with Sutherland Reservoir, will drown over half of the San Pasqual Valley ground-water basin more than 50 per cent of the time. This condition will make utilization of the basin on a safe yield basis impracticable from the operating standpoint. However, the basin will be available as an emergency source of supply during drought periods, and water in the total amount of approximately 13,000 acre-feet can then be obtained.

Reduction of Natural Consumptive Use
Conservation of water lost by consumptive use of native vegetation in San Dieguito Basin is considered practicable only in San Pasqual Valley, where, through lowering of the water table below the root zone a sufficient distance and maintaining it at that elevation, a moderate amount of water can be salvaged by a program of pumping and delivering the water into Lake Hodges.

A complete field survey of irrigated crops and native vegetation in San Pasqual Valley was conducted in 1945. Aerial photographs covering the valley, taken in the year 1939, also are available, from which a reasonably accurate picture of culture in 1939 was obtained. As is shown in Table 42 (page 143), a small decrease in the area given over to irrigated agriculture occurred between 1939 and 1945. However, for purposes of this study the mean between 1939 and 1945 survey values was taken as representing present conditions.

Unit values of consumptive use were based on preliminary estimates made by the Soil Conservation Service of the United States Department of Agriculture, at the request of and in cooperation with the Division of Water Resources*. These values were derived from experimental data obtained by the Soil Conservation Service in connection with its comprehensive hydrologic investigation of the adjacent San Luis Rey Valley, and were adjusted to conditions existing in San Pasqual Valley. Application of unit consumptive use values to areas of native vegetation and man-made culture determined by the crop surveys results in an estimate of total gross seasonal consumptive use in San Pasqual Valley, under present

* Preliminary Progress Report, "Consumptive Use of Water Investigations in San Pasqual Valley, California", Division of Irrigation, Soil Conservation Service, U. S. Department of Agriculture, September 14, 1945, included as Appendix D, herein.

conditions, of approximately 8,800 acre-feet. Of this total seasonal use in San Pasqual
Valley, about 1,400 acre-feet constitute consumptive use by man-made culture, while the
remaining 7,400 acre-feet are lost through consumptive use by native vegetation, or evapo-
ration from soil and natural water surfaces.

TABLE 42

ESTIMATED GROSS SEASONAL CONSUMPTIVE USE
BY IRRIGATED CROPS IN SAN PASQUAL VALLEY

Type of Crop	1939 Crop Survey			1945 Crop Survey		
	Area in Acres	Consumptive Use		Area in Acres	Consumptive Use	
		in Feet of Water	in Acre-Feet		in Feet of Water	in Acre-Feet
Alfalfa	124.8	3.4	424	225.4	3.4	766
Sudan grass	71.8	3.4	244	70.2	3.4	239
Grain	5.8	1.5	9	0	1.5	0
Field crops	243.9	1.5	366	115.4	1.5	173
Orchard	68.8	2.4	165	44.3	2.4	106
TOTALS	515.1		1,208	455.3		1,284

1939 and 1945 Crop Surveys	
Mean area of irrigated crops	485 acres
Mean unit consumptive use	2.57 feet of water
Mean total consumptive use	1,246 acre-feet

In order to determine the amount of water that might be salvaged in San Pasqual
Valley by lowering the ground water from its normal levels, consumptive use was estimated
with water levels successively lowered by stages to a maximum of eight feet. It was as-
sumed that present irrigated agricultural crops would be maintained by surface irrigation.
Unit consumptive use values for various depths of water table below the ground surface
were likewise based on data secured from the Soil Conservation Service. Results of apply-
ing these consumptive use values to present types of vegetation throughout the valley are
listed in Table 43 (page 144), and shown graphically on Plate XV, "Effect of Lowering Av-
erage Levels of Ground Water on Total Gross Seasonal Consumptive Use in San Pasqual Val-
ley". It may be noted that by lowering the ground water eight feet below the normal level
a theoretical saving of approximately 4,750 acre-feet can be effected seasonally. Further-
more, over 75 per cent of this salvage results from an average lowering of the ground water
of only two feet, and over 92 per cent from a lowering of four feet. It is probable that
in actual practice, however, the salvage from natural losses in San Pasqual Valley will be
only about 50 per cent efficient.

TABLE 43

ESTIMATED GROSS SEASONAL
CONSUMPTIVE USE IN SAN PASQUAL VALLEY
WITH WATER TABLE AT VARIOUS ELEVATIONS
UNDER PRESENT CONDITIONS OF CULTURE

Average Ground-Water Levels	Total Consumptive Use in Acre-Feet
Normal	8,800
Lowered one foot	6,490
Lowered two feet	5,200
Lowered three feet	4,640
Lowered four feet	4,390
Lowered five feet	4,220
Lowered six feet	4,130
Lowered eight feet	4,050

If the City of San Diego, in securing water rights in San Pasqual Valley requir-
ed for construction of a larger Lake Hodges, acquires the entire valley floor, it can prob-
ably conserve an estimated 2,000 acre-feet per season by reducing consumptive use of na-
tive vegetation, and at the same time allow full irrigation of presently irrigated lands
in the upper end of the valley. This will involve installation of a system of wells,
pumps and pipe lines to systematically lower the water table, and dump the conserved water
into Lake Hodges. The increment to gross evaporation from Lake Hodges caused by this
relatively small amount of additional supply will be inconsequential except during rare
periods of very low reservoir stages, since the reservoir water surface area will not be
materially increased at normal stages. In operation of such a conservation project, the
upper portion of the ground-water basin will automatically be utilized for cyclic storage,
as the basin will probably refill in all except extremely dry years.
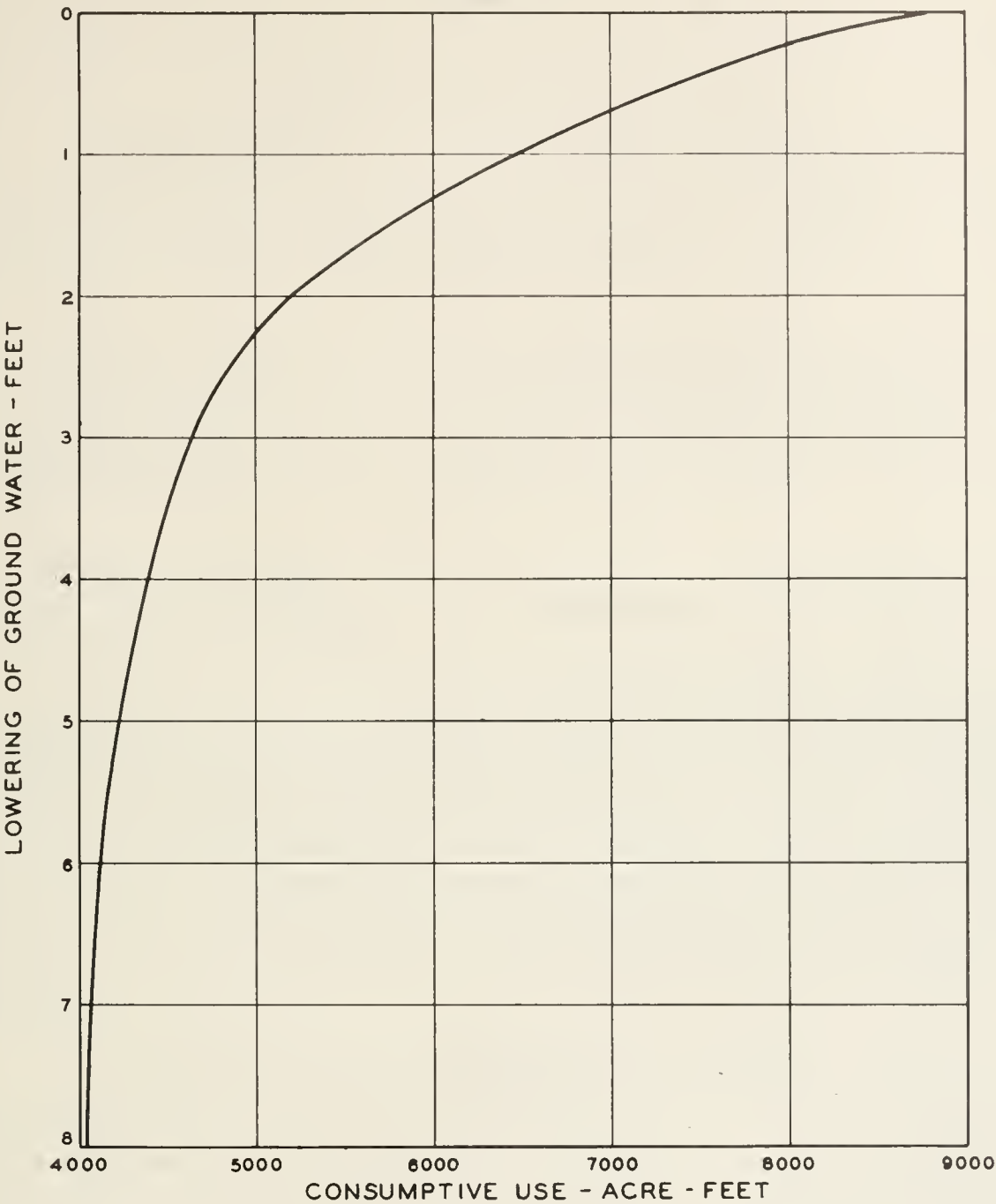
PLATE XV

EFFECT OF LOWERING AVERAGE LEVELS OF
GROUND WATER ON TOTAL GROSS SEASONAL
CONSUMPTIVE USE IN SAN PASQUAL VALLEY

CHAPTER VIII

FLOOD CONTROL WORKS IN SAN DIEGUITO BASIN

The general statements presented in Bulletin No. 48 relative to history of floods, characteristics of flood occurrence, and variation of flood flows on San Diego County streams are directly applicable to San Dieguito River. The following discussion of floods and flood control is largely limited to developing and presenting the effect of conservation reservoirs upon floods in San Dieguito Basin.

Flood flows in San Dieguito Basin are under further stu..y by the Division of Water Resources in connection with a State-wide investigation of water resources, authorized by Chapter 1541, Statutes of 1947. The results of these more refined studies may vary in detail from those presented herein, but it is believed that they will not be such as to modify present conclusions and recommendations with respect to flood control on San Dieguito River.

Areas Subject to Flood Damage

Overflow and damage by floods in San Dieguito Basin occur principally in San Pasqual and San Dieguito valleys.

San Pasqual Valley lies between elevations 350 and 460 feet, and extends along the river for approximately 5.5 miles, with an approximate average width of 3,000 feet. The transversely level valley floor comprises about 2,100 acres, of which only about 485 acres are devoted to irrigated crops. The remainder of the area is given over to native vegetation, including about 1,250 acres of salt grass pasture, and stream channel. Most of the cropped land and improvements are located in the upper one and one-half miles of the valley, which is least subject to overflow. Throughout the remainder of the valley the river channel is shallow, and between floods becomes choked with dense growth of native brush. Capacity of the channel is so limited that the larger portion of the valley is subject to overflow with only moderate floods, while large floods menace the entire 2,100 acres of valley floor.

San Dieguito Valley extends upstream from the coast highway a distance of approximately six miles, and derives only negligible flood protection from Lake Hodges, some five miles above it. The valley floor, as measured from U. S. G. S. maps, covers an area of approximately 2,800 acres, and has an average width of approximately 3,800 feet. Culture of irrigated crops is confined to an area of about 1,000 acres, largely in the upper part of the valley. Because of past flood experiences, the area given over to permanent crops and improvements within the valley floor is limited. San Dieguito Valley, for its lowermost one and one-half miles, was originally a tidal marsh, but near the ocean there are now concentrated a number of improvements, consisting of the Del Mar Turf Club and San Diego County Fair grounds, highway, railroad, and utility crossings, and a number of beach homes between the highway and ocean. The turf club and fair grounds, located on property of the 22nd District Agricultural Association, would be completely inundated by a large flood under present conditions. Short span portions of highway and railroad crossings would also be damaged, and a small number of beach homes probably seriously damaged or destroyed.

Flood Characteristics

While general characteristics of floods in San Diego County were described in
Bulletin No. 48, it was necessary during the present investigation to make detailed
studies of size and frequency of flood flows in San Dieguito Basin, as well as analyses
of flood hydrographs. These data were used largely in determining probable effects of
proposed conservation reservoirs on flood flows.

Size and Frequency of Flood Flows

In Table 44 are listed runoff characteristics of the maximum flood of record in
San Dieguito Basin, that of January 27, 1916.

TABLE 44

MAXIMUM FLOOD OF RECORD IN SAN DIEGUITO BASIN

January 27, 1916

Location	Mean Daily Flow in Second-Feet		Peak Flow in Second-Feet	
	Total	per Square Mile	Total	per Square Mile
Sutherland dam site	10,800	200	21,100	390
Pamo dam site	14,100	127	28,400	256
Hodges Dam	37,200	123	72,100	238

Probable size and frequency of mean daily flood flows at Sutherland, Pamo and
Hodges dam sites, under present conditions, are tabulated in Table 45, and shown graphic-
ally on Plate XVI, "Probable Frequency of Occurrence of Floods in San Dieguito Basin".

TABLE 45

ESTIMATED MAGNITUDE AND FREQUENCY OF MEAN DAILY FLOOD FLOWS
IN SAN DIEGUITO BASIN UNDER PRESENT CONDITIONS

Location	Tributary Drainage Area in Square Miles	Period of Record Utilized in Study		Mean Daily Flows Equaled or Exceeded, in Second-Feet, Probably Occurring on the Average Once in				
		Inclusive Dates	Number of Years	10 Years	25 Years	50 Years	100 Years	250 Years
Sutherland dam site	54	1913-1924 1936-1947	23	4,000	7,000	9,000	12,000	16,000
Pamo dam site	111	1906-1923	17	8,000	14,000	19,000	24,000	32,000
Hodges Dam	303	1906-1930	25	14,000	27,000	38,000	52,000	70,000

The foregoing estimates of probable flood frequencies at Sutherland dam site are
based upon the 23 years of available runoff record of Santa Ysabel Creek near Mesa Grande.
These records cover the periods from January 1913 to September 1924, and from October 1936
to September 1947, inclusive. It will be noted that the period covered does not include

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PLATE XVI
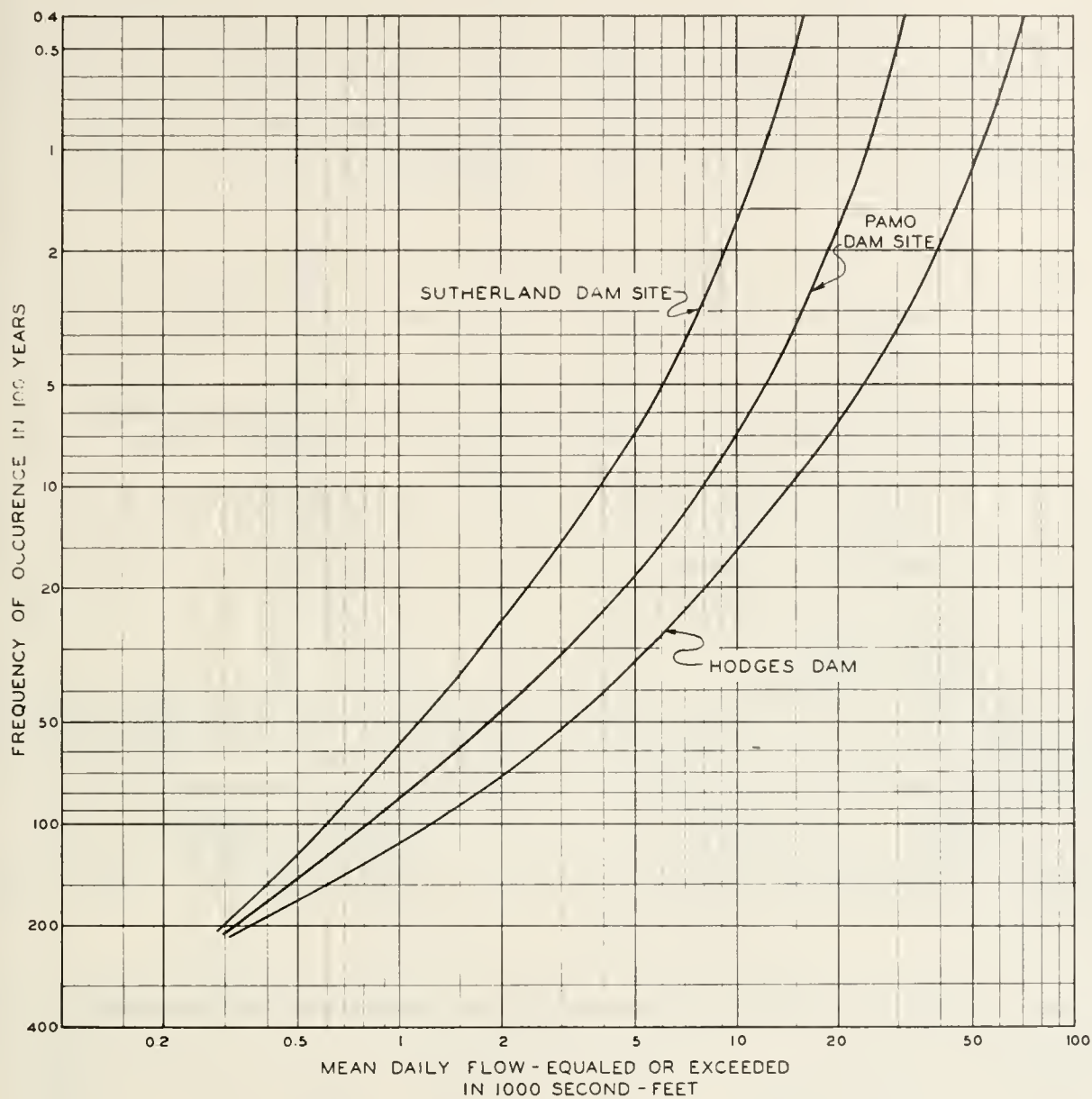
PROBABLE FREQUENCY OF OCCURENCE
OF
FLOODS IN SAN DIEGUITO BASIN
UNDER PRESENT CONDITIONS

the February 1927 flood, which flood was probably next in magnitude to that of February 1916. Probable flood frequencies at Pamo dam site are based upon runoff records of Santa Ysabel Creek near Escondido for the period from 1906 to 1911, and upon records for Santa Ysabel Creek near Ramona for the period from 1912 to 1923. Estimated flood frequencies at Hodges Dam, presented herein, are taken from Bulletin No. 48, and were based upon the 25-year period from 1906 to 1930. Mean daily flood flows for the period from 1906 to 1912 were estimated from recorded flows of Santa Ysabel Creek near Escondido. Flood flows for the period from 1912 to 1916 were based upon recorded flows of San Dieguito River at Bernardo, with estimated contribution of the drainage area between Bernardo and Hodges Dam added. Runoff records directly applicable to Hodges Dam were available for the period from 1916 to 1930.

The method used in estimating probable size and frequency of flood flows was as follows:

1. Mean daily flows of each flood of record were listed in order of their magnitude.

2. The number of times a given mean daily flow was equaled or exceeded in the period of record was converted to the number of times the flow would be equaled or exceeded in 100 years, by multiplying by the number of times the period of record was contained in 100 years.

3. Values of mean daily flows were plotted on a logarithmic graph in relation to their frequencies.

4. Trend of the plotted points was extended by a smooth curve through and beyond the plotted points.

Flood Hydrographs

Only a few hydrographs of flood flows on San Dieguito River are available, and most of these have been computed from records of reservoir operation, or from observed gage heights and rating curves extended by estimates of flow based on surface velocities or Kutter's formula. In consequence, they are considered only approximate. Available flood hydrographs at Sutherland and Pamo dam sites and at Hodges Dam are shown on Plate XVII, "Hydrographs of Floods of Record in San Dieguito Basin", wherein peak flow is expressed as its ratio to maximum mean 24-hour flow. It will be noted that a computed mean hydrograph has been drawn for each of the three sites.

In order to evaluate possible effect of the several reservoirs on floods, and to establish spillway and freeboard requirements, it was necessary to compile a design, or "probable" hydrograph of flood flow under present conditions. The ratio of crest flow to maximum mean 24-hour flow, for various floods of record at the three proposed reservoir locations, is given in Table 46 (page 152). Hydrographs of design floods for the three locations are shown on Plate XVIII, "Probable Hydrographs of Flood Flows in San Dieguito Basin", in which the hourly rate of flow is expressed as a ratio of the maximum mean 24-hour rate, and may be converted to second-foot values for a given frequency of flood by applying mean daily flood flows given in Table 45.

The mean hydrograph for the Sutherland site, shown on Plate XVII, was accepted as the design flood hydrograph for that location. In this case the ratio of crest flow to maximum mean 24-hour flow is 3.11 to 1.0. Duration of recorded flood crests at the mean maximum 24-hour rate varies from five to eight and one-half hours. Corresponding duration on the probable flood hydrograph is seven hours, while average volume of the crest above the mean 24-hour rate is 28 per cent of maximum 24-hour volume.

PLATE XVII
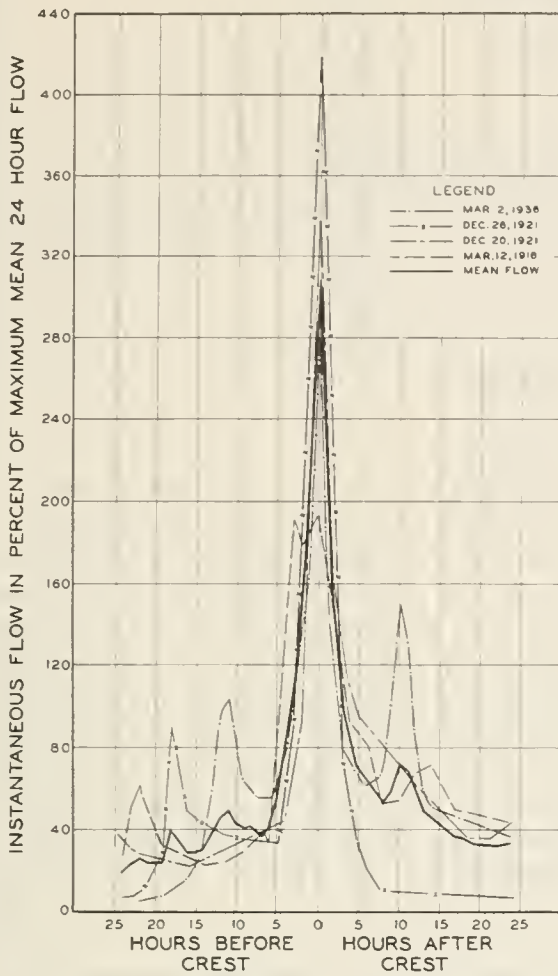
SUTHERLAND DAM SITE
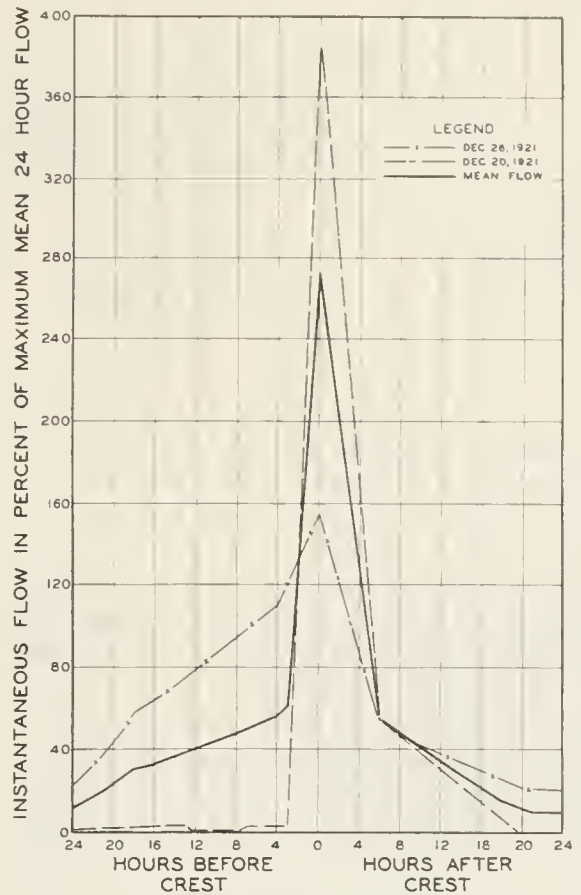
PAMO DAM SITE
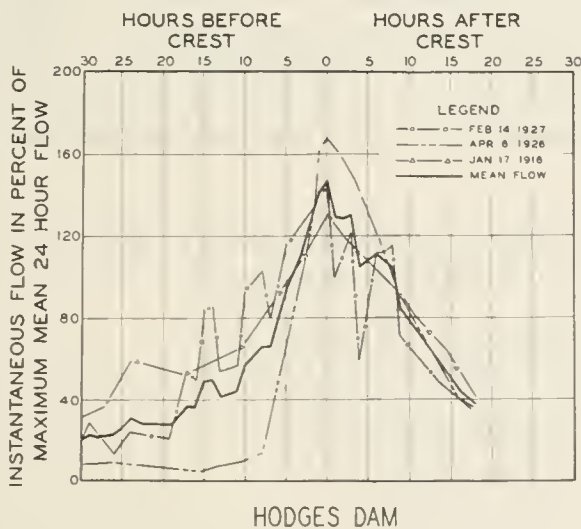
HODGES DAM

HYDROGRAPHS
OF
FLOODS OF RECORD
IN
SAN DIEGUITO BASIN

TABLE 46

RATIO OF CREST FLOOD FLOWS TO
MAXIMUM MEAN 24-HOUR FLOWS
IN SAN DIEGUITO BASIN

Ratio to Unity

Location	Date of Occurrence							
	Jan. 17, 1916	Jan. 27, 1916	Mar. 12, 1918	Dec. 20, 1921	Dec. 26, 1921	Feb. 16, 1927	Mar. 2, 1938	Average
Sutherland dam site			1.95	3.38	4.26		2.84	3.11
Pamo dam site				3.94	1.58			2.76
Hodges Dam	1.31	1.67				1.45		1.48

For Pamo dam site the probable hydrograph has a ratio of crest flow to mean maximum 24-hour flow of 2.8 to 1.0. The 54 square miles of drainage area above Sutherland and the 57 square miles between Pamo and Sutherland are quite similar in length, elevation, range and slope. However, mean elevation of the basin above Sutherland is greater than that for the area between Sutherland and Pamo. It is estimated, from observed variation of rainfall intensity with elevation, that the area above Sutherland contributes 51 per cent of a major flood flow at Pamo dam site. Channel distance between the two points is approximately six miles and is traversed by flood flows in about an hour. Proportions of the probable hydrograph of Pamo were therefore determined by the summation of two probable hydrographs for Sutherland dam site, with a lag of one hour between them, the hydrographs being adjusted in the proportions of 0.49 to 0.51, in accordance with the runoff ratio discussed above. Volume and shape of the resulting flood crest are similar to those for the mean hydrograph shown on Plate XVII.

At Hodges Dam the mean ratio of crest flood flow to maximum mean 24-hour flow, for three floods listed in Table 46, is 1.48 to 1.00. However, analysis of available hydrographs of floods on other streams in San Diego County indicated that the mean hydrograph on Plate XVII was not representative of flood conditions to be expected at Hodges Dam. The probable hydrograph of flood flow at Hodges Dam, shown on Plate XVIII, is therefore based on mean hydrographs of floods occurring not only in San Dieguito River at Lake Hodges, but also in San Luis Rey River near Mesa Grande and San Diego River near Santee, in adjoining drainage basins. Resultant probable crest flow is 1.70 times the maximum mean 24-hour flow.

Estimated frequency and magnitude of probable crest flood flows at Sutherland and Pamo dam sites, and at Hodges Dam, are listed in Table 47 (page 154).

PLATE XVIII
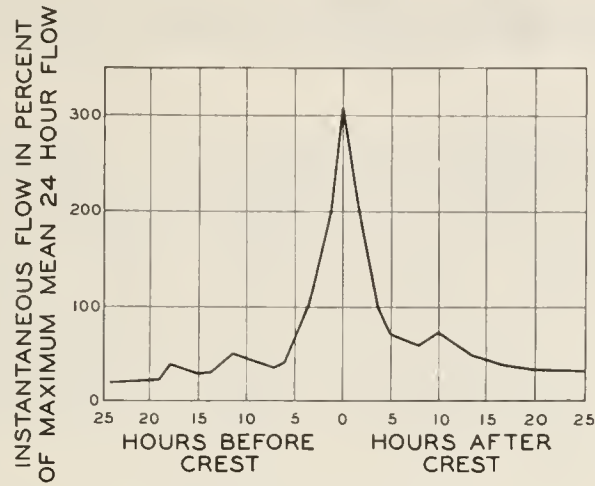
SUTHERLAND DAM SITE
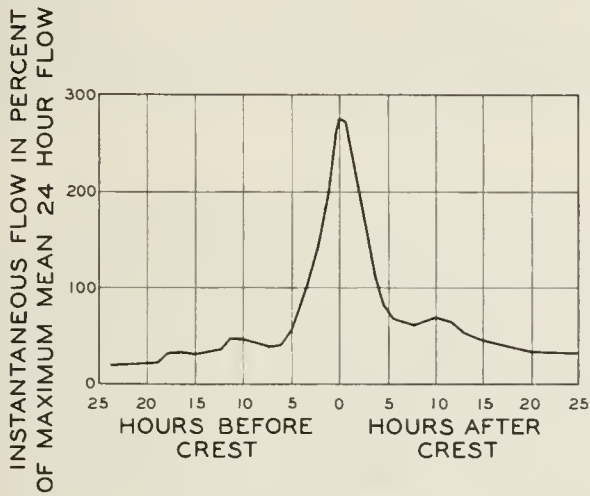
PAMO DAM SITE
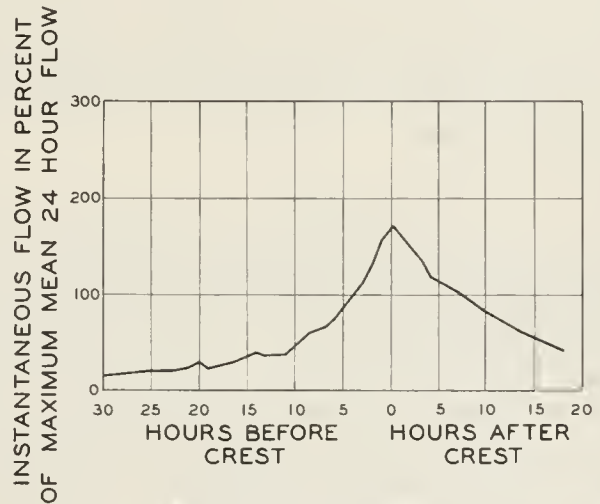
HODGES DAM SITE

PROBABLE HYDROGRAPHS OF FLOOD
FLOWS IN SAN DIEGUITO BASIN
UNDER PRESENT CONDITIONS

TABLE 47

ESTIMATED SIZE AND FREQUENCY OF CREST FLOOD FLOWS
IN SAN DIEGUITO BASIN UNDER PRESENT CONDITIONS

Location	Tributary Drainage Area		Ratio of Crest to Maximum Mean 24-Hour Flow	Crest Flow, Equaled or Exceeded, in Second-Feet, Probably Occurring on the Average Once in			
	Area in Square Miles	Average Elevation in Feet		25 Years	50 Years	100 Years	250 Years
Sutherland dam site	54	3,350	3.11	21,800	28,000	37,300	49,800
Pamo dam site	111	2,900	2.80	39,200	53,200	67,200	89,600
Hodges Dam	303	1,900	1.70	45,900	64,600	88,400	119,000

Flood Control

On the basis of preliminary studies, the control of large floods in San Pasqual and San Dieguito valleys solely by levees or channel improvements is not considered to be economically feasible at this time, with possible exception in the case of a short channel at the lower end of San Dieguito Valley. Adequate flood channels in these valleys would occupy areas out of proportion to the lands and improvements protected. Levees constructed from the friable native soils would require expensive protection, and costly connections to lateral drainage channels would be necessary. Maintenance costs would be high on some portions of channel, due to the heavy growth of brush and trees encouraged by the high water table.

It is reasonable to suppose that some degree of flood control in San Dieguito Basin, by reservoirs alone or in combination with improved channels, might be justified. However, in the San Diego region conservation of water is paramount, and a plan of reservoir operation which would reduce the catchment for conservation could only be considered if protection were offered to a highly developed area of concentrated population and culture. Such is not the case at present in San Dieguito Basin. Any flood control reservation in reservoirs under consideration would reduce their catchment for conservation. In this study, no attempt has been made to determine economic feasibility of providing reservoir storage space exclusively for flood control purposes, supplementary to requirements for conservation. However, it has been found that a considerable reduction in size and frequency of crest flood flows on San Dieguito River below Lake Hodges would automatically result from normal operation of the complete development for conservation purposes.

Effect of Conservation Reservoirs

Sutherland Reservoir

The 54 square miles of watershed above Sutherland Dam constitute only about 40 per cent of the drainage area tributary to the upper end of San Pasqual Valley. This valley is the first downstream area in San Dieguito Basin subject to appreciable flood damage from Santa Ysabel Creek. Although the Sutherland watershed is of relatively high runoff productivity, it contributes only about one-half of the flood waters reaching San Pasqual Valley. The valley, therefore, would be subject to continuing flood damage, even though Sutherland Reservoir were completely effective as regards flood control. However, no such control would be realized from a reservoir of 36,700 acre-foot capacity at the

Sutherland site, the size which would be obtained by completing the dam as originally planned. This capacity is relatively small as compared with runoff at the site during flood seasons. Since it is assumed that the reservoir would be operated exclusively for conservation purposes, it might be full, or nearly full, to crest of spillway drum gates at times of occurrence of peak flood flows. With drum gates, there could be no storage of flood waters above the conservation pool level, and possible faulty gate operation might actually increase downstream peak flows. Effect of Sutherland Reservoir upon the probable once in 100-year flood is shown on Plate XIX, "Effect of Conservation Reservoirs in San Dieguito Basin on Crest Flows of Probable Once in 100-Year Flood".

Under the plan for complete conservation development of San Dieguito Basin recommended herein, a conservation reservoir of 310,000 acre-foot capacity is proposed at the Hodges site, to be operated coordinately with the completed Sutherland Reservoir. This enlargement of Lake Hodges would flood more than 1,200 acres, or nearly 60 per cent of the entire floor of San Pasqual Valley, and any possible benefits from reservoir flood control at Sutherland would be confined to the remaining relatively small area. They would be of minor significance and undependable.

The effects of Sutherland Reservoir on flood flows in San Dieguito Valley would be negligible. Sutherland Reservoir controls only a little over 15 per cent of the drainage area above San Dieguito Valley, and the Sutherland watershed contributes less than one-quarter of the flood waters reaching the valley. Furthermore, it will be shown hereinafter that under the recommended plan for complete conservation development of San Dieguito Basin, the enlarged Lake Hodges in itself would provide a very large measure of flood protection to San Dieguito Valley, and would render insignificant any effects attributable to Sutherland Reservoir.

Pamo Reservoir

Flood control storage at Pamo Reservoir would materially reduce crest flood flows in San Pasqual Valley. On the basis of the probable flood hydrograph of Plate XVIII, crest flows at Pamo dam site could be reduced 50 per cent by flood control storage amounting to 16 per cent of the maximum 24-hour flood volume. For a once in 100-year flood, this flood control storage reservation would amount to approximately 8,000 acre-feet. A conservation reservoir at Pamo, with capacity of 163,400 acre-feet, and with spillway crest 200 feet in length, would reduce the once in 100-year peak flood flow from 67,000 to 31,000 second-feet, by temporary storage above the spillway crest. This is illustrated in Plate XIX. However, it has been shown in Chapter VII that under any plan for development of San Dieguito Basin which included a reservoir at the Pamo site, Lake Hodges would have to be enlarged to a capacity of at least 174,400 acre-feet, in order to conserve runoff originating between Pamo and Hodges. Such enlargement of Lake Hodges would inundate about one-half of the floor of San Pasqual Valley, and benefits from reservoir flood control at Pamo would be necessarily confined to the remainder.

Under present conditions, with the existing Lake Hodges, effects of flood control storage at Pamo Reservoir would be material as far downstream as San Dieguito Valley. However, with Lake Hodges enlarged to the capacity required for complete conservation development of the basin under coordinated operation with Pamo Reservoir, the enlarged Lake Hodges in itself would provide a very large measure of flood protection to San Dieguito Valley. Flood control effects of Pamo Reservoir in San Dieguito Valley would be minimized.

Comparative costs of additional yield from San Dieguito Basin reservoirs, as presented in Chapter VII, do not favor conservation development at Pamo. Flood control benefits that may be attributed to Pamo Reservoir are insufficient to alter this relationship.

Lake Hodges

It has been stated that an enlarged Lake Hodges would provide a substantial amount of flood protection to San Dieguito Valley. The amount of storage capacity required to regulate flood flows to a given proportion of their unregulated peak discharges at Hodges Dam, expressed as a ratio of mean daily flood volume, is shown by the uppermost graph of Plate XX, "Flood Control Effects of Lake Hodges on San Dieguito River". From the graph it may be determined that storage capacity equal to 22 per cent of the mean daily flood volume would be required to regulate crest flood flows to 50 per cent of their unregulated rate. This amounts to a storage reservation of 23,000 acre-feet for a once in 100-year flood. However, the reservoirs under consideration in this study should be operated for conservation. The provision of storage exclusively for flood control purposes may not be justified in this instance, in view of the incidental protection afforded by a large conservation reservoir at the Hodges site.

The effect of conservation storage at Lake Hodges on crest flood flows in San Dieguito River is shown on both plates XIX and XX. By ponding or temporary storage above the spillway crest level, a conservation reservoir with capacity of 157,300 acre-feet would reduce peak flow of the probable once in 100-year flood from 88,400 to about 57,000 second-feet, or approximately 65 per cent of the unregulated flow. Similarly, a conservation reservoir with capacity of 224,800 acre-feet would achieve a reduction of the 100-year crest flood discharge to about 50,000 second-feet, while one of 340,700 acre-foot capacity would reduce such a flood peak to about 48,000 second-feet, or approximately 54 per cent of the unregulated rate of flow. No attempt has been made to evaluate flood protection benefits to San Dieguito Valley which would result from construction of an enlarged Lake Hodges, to be operated exclusively for conservation purposes. It is apparent, however, that such benefits would be substantial, and that a portion of the capital costs of the conservation reservoir could properly be charged to flood control.

In addition to the foregoing direct reduction of flood peaks resultant from a large conservation reservoir at Lake Hodges, there would be small probability of floods occurring when such a reservoir was full. The probable amount of storage space available on April 1st in a large reservoir at Hodges operated exclusively for conservation purposes can be derived from the curve on Plate XXI, "Probable Volume of Water in Storage at Lake Hodges on First of April". The 24-hour volume of the probable once in 25-year flood at Hodges Dam is 53,600 acre-feet, or about 16 per cent of the storage capacity of a 340,700 acre-foot reservoir. Water in storage on April 1st would equal or exceed 84 per cent of total reservoir capacity in about 16 years in 100, on the average. The flood, therefore, could be accommodated within available reservoir space 84 years out of a hundred, on the average, or 84 per cent of the time. In the same manner, it may be ascertained that the maximum 24-hour volume of a probable once in 50-year flood would be available, on the average, about 78 per cent of the time.

The probable frequency of occurrence of a given regulated flood crest discharge may be estimated by combining probable frequencies of occurrence of vacant reservoir storage space, and of crest flood flows. For all reservoir stages above the spillway lip,

PLATE XIX
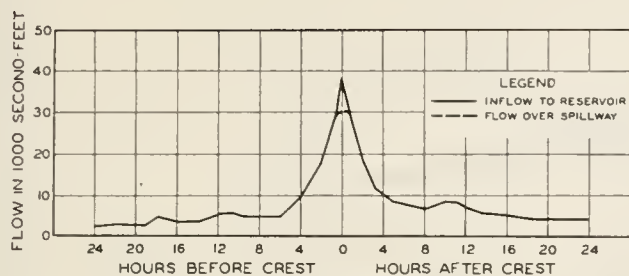
SUTHERLAND DAM SITE
MEAN DAILY FLOW 12,000 SECOND-FEET
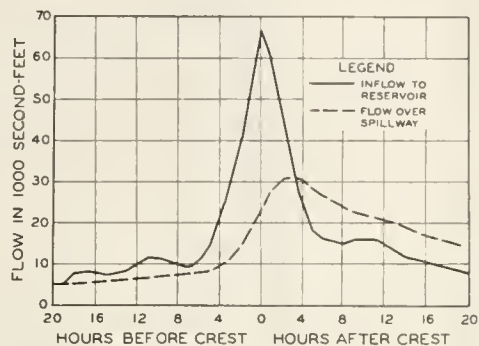
PAMO DAM SITE
MEAN DAILY FLOW 24,000 SECOND-FEET
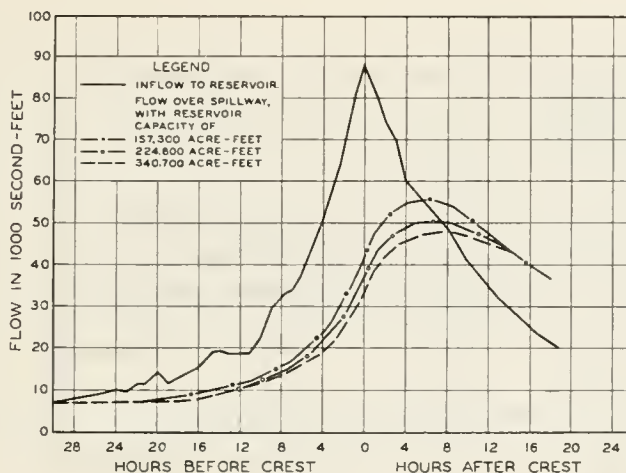
HODGES DAM
MEAN DAILY FLOW 52,000 SECOND-FEET

NOTE
RESERVOIRS ASSUMED FULL TO
SPILLWAY CREST AT TIMES OF FLOOD
OCCURRENCE

EFFECT OF CONSERVATION RESERVOIRS
IN
SAN DIEGUITO BASIN
ON
CREST FLOWS
OF
PROBABLE ONCE IN 100-YEAR FLOOD

PLATE XX
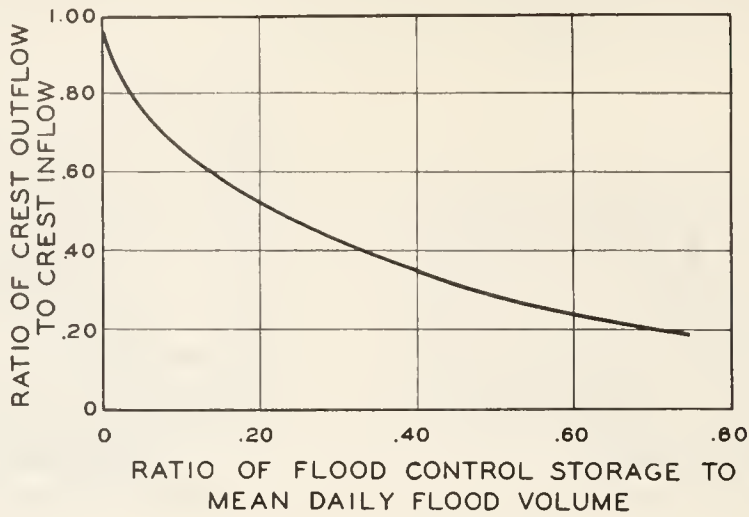
WITHOUT FLOOD CONTROL RESERVATION
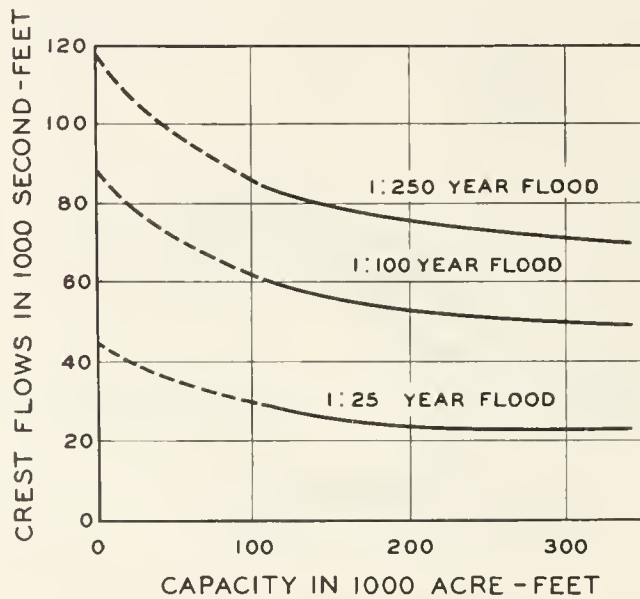
WITH FLOOD CONTROL RESERVATION

FLOOD CONTROL EFFECTS
OF LAKE HODGES
ON SAN DIEGUITO RIVER

PLATE XXI

STORAGE VOLUME EQUALED OR EXCEEDED
IN PERCENT OF TOTAL CAPACITY
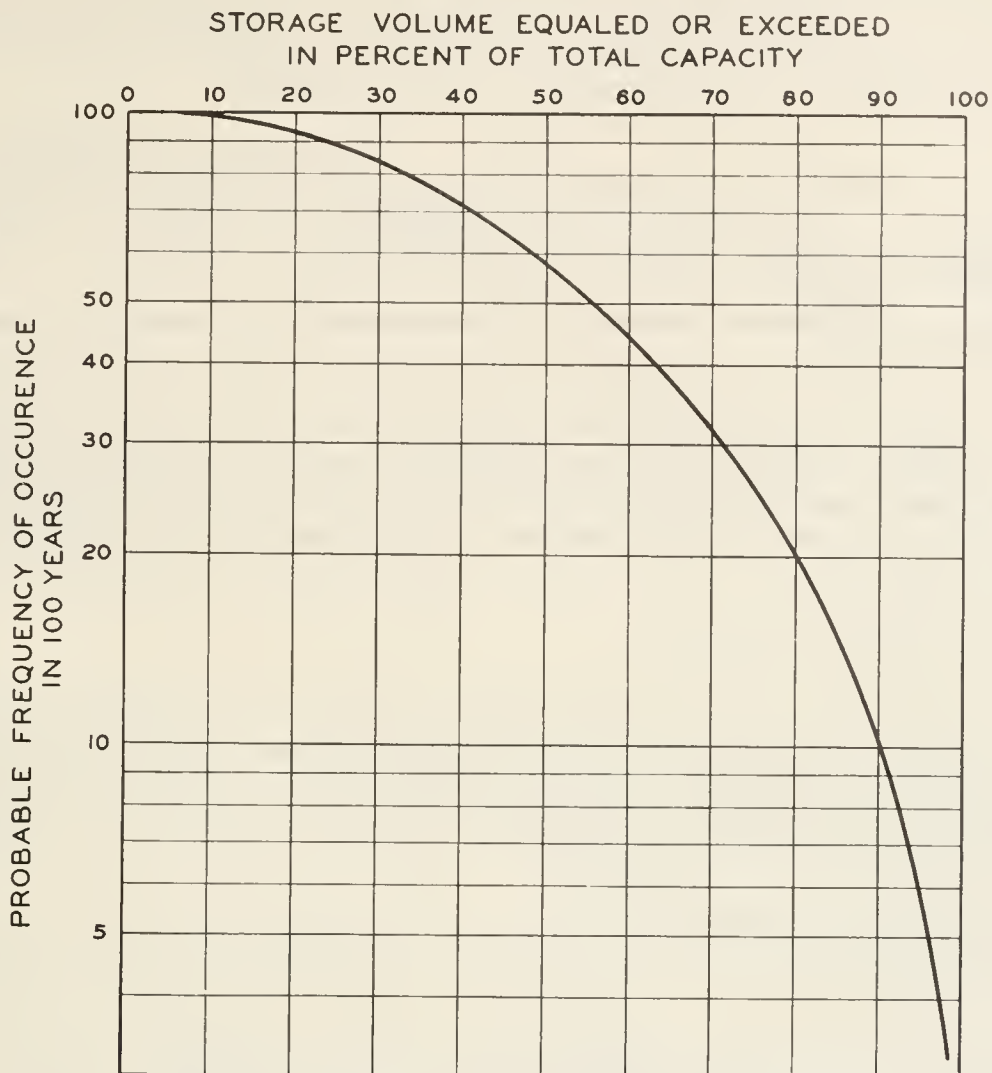
PROBABLE VOLUME OF WATER IN
STORAGE AT LAKE HODGES
ON FIRST OF APRIL

Based on 340,700 Acre-Foot Reservoir
Operated for 1917-36 Firm Yield

(Reservoir Assumed Full on April 1, 1916)

routing of the flood through the reservoir is involved. If probable frequencies of occurrence of vacant storage space and of floods at Lake Hodges are combined as unrelated events, by statistical methods, the probable frequencies of occurrence of given regulated crest flood flows below Hodges Dam are as tabulated below. Frequencies for the regulated flood are based upon 310,000 acre-feet of storage capacity in Lake Hodges, operated for conservation purposes.

	Crest Discharge in Second-Feet		
	45,900	64,600	88,400
Unregulated flood, probable frequency of occurrence, once in	25 years	50 years	100 years
Regulated flood, probable frequency of occurrence, once in	215 years	320 years	440 years

The upper limits of magnitude and frequency of occurrence of floods to which the foregoing analysis or reasoning may be applied are not definite. However, it is observed that complete development of San Dieguito Basin for water conservation, as defined earlier in this report, would have completely retained all flood flows of the past 42 years, from 1906 to 1948, inclusive.

Future Flood Control Works

Findings of the present studies support the conclusion that complete development of San Dieguito Basin for conservation will limit future flood control works to the portion of the basin below Hodges Dam, namely, San Dieguito Valley. As was developed in Bulletin No. 48 and mentioned heretofore, water conservation is the primary consideration in the San Diego region, and storage space reserved for flood control should be considered only above that required for conservation.

A conservation reservoir at Lake Hodges with storage capacity exceeding 225,000 acre-feet would reduce crest flow of the probable once in 100-year flood by not less than 40 per cent. In addition to this direct reduction of large flood crests by temporary storage above the spillway level, with complete development of San Dieguito Basin for conservation there would usually be sufficient vacant storage space available to absorb most floods having a magnitude less than the probable once in 50-year flood. It therefore may be concluded that some proportion of the cost of a large conservation reservoir at Lake Hodges could properly be charged to flood control. The amount of such participation should be based on capitalization of the reduction in estimated average annual flood damages. Studies of probable future flood damage should recognize the percentage of time that vacant storage space would be available in conservation reservoirs, as well as the effects of temporary storage above spillway levels.

CHAPTER IX

CONSERVATION WORKS ON SAN DIEGO RIVER

Bulletin No. 48 presented a plan contemplating the most economic complete de-velopment, utilization and control of waters of the San Diego River for all consumptive purposes and for flood control, in coordination with the then existing development. This plan included a reservoir on San Vicente Creek and one on San Diego River in Mission Gorge. San Vicente Reservoir has since been constructed by the City of San Diego, but to a smal-ler capacity than was recommended in the 1935 report. As regards reservoirs in Mission Gorge, Bulletin No. 48 presented studies and cost estimates for two alternative sites, namely, Mission Gorge Reservoir No. 2 and Mission Gorge Reservoir No. 3, and it was shown that the first of these was the more favorable economically. A current comparison of res-ervoirs in Mission Gorge is presented in this chapter, and studies for an additional site, Mission Gorge No. Zero, have been included. A cost estimate has also been prepared for increasing the size of San Vicente Reservoir to provide additional capacity suggested by the City of San Diego for storage of imported water, as well as for conservation of local supplies.

Mission Gorge Reservoirs

Mission Gorge No. Zero dam site is located about 1,000 feet upstream from the Old Mission Dam, at the extreme upper end of Mission Gorge. Mission Gorge No. 2 dam site is approximately three-quarters of a mile downstream, at a point 3,100 feet below Old Mission Dam. The No. 3 dam site is a further 1.8 miles downstream, and about one-half mile above the upper end of Mission Valley. Streambed elevation at the Mission Gorge No. Zero site is 278 feet, compared with 244 feet at the No. 2 site and 100 feet at the No. 3 site.

Areas and Capacities

An aerial topographic survey of the Mission Gorge reservoir area was made by Fairchild Aerial Surveys, Inc., in July 1945, in connection with the present investiga-tion. The survey included elevations up to 350 feet, and extended downstream sufficiently far to include dam site No. 3, the lowest site. The following maps were compiled from the survey, by Fairchild Aerial Surveys, Inc.:

    (a) Mission Gorge Reservoir Topography, San Diego River
        topography: scale 1 inch = 400 feet; contour interval, 10 feet;
        in 2 sheets.
        triangulation: scale 1 inch = 2,000 feet.
    (b) Mission Gorge No. Zero Dam Site
        topography: scale 1 inch = 200 feet; contour interval, 10 feet.

Areas and capacities of the three reservoirs, computed from data of the 1945 sur-vey, are given in Table 48 (page 162). Reservoir storage capacities, computed from areas measured on the more accurate topographic maps made in 1945, differ a little from capaci-ties given in Bulletin No. 48 for Mission Gorge reservoirs Nos. 2 and 3. The 1945 survey found 2,230 acre-feet less capacity at elevation 330 feet, and 3,050 acre-feet less at elevation 350 feet, for Mission Gorge Reservoir No. 2. Dams at this site would therefore

have to be from 1.2 feet to 1.5 feet higher than those described in Bulletin No. 48, in order to provide storage capacities considered therein. Similarly, a dam at Mission Gorge No. 3 site to provide 29,200 acre-feet of storage capacity would have to be 1.0 feet higher than contemplated in Bulletin No. 48. However, for remaining reservoir capacities considered in Bulletin No. 48 for the No. 3 site, results of the 1945 survey made no appreciable difference in heights of dams.

TABLE 48

AREAS AND CAPACITIES OF
MISSION GORGE RESERVOIRS

Based on 1945 Topographic Survey
by Fairchild Aerial Surveys, Inc.

Elevation (U.S.G.S.) Datum in Feet	Dam Site No. 3		Dam Site No. 2		Dam Site No. Zero	
	Water Surface Area in Acres	Capacity in Acre-Feet	Water Surface Area in Acres	Capacity in Acre-Feet	Water Surface Area in Acres	Capacity in Acre-Feet
97	0	0				
100	0	0				
110	1	7				
120	6	42				
130	14	139				
140	18	297				
150	22	497				
160	28	745				
170	40	1,084				
180	47	1,522				
190	56	2,036				
200	68	2,655				
210	80	3,398				
220	90	4,253				
230	104	5,227				
240	120	6,348	0	0		
250	136	7,630	2	9		
260	160	9,110	7	51		
270	188	10,848	16	163	0	0
280	221	12,895	30	394	1	7
290	280	15,401	63	863	28	153
300	404	18,818	163	1,994	121	896
310	629	23,978	359	4,602	308	3,037
320	977	32,006	674	9,768	612	7,635
330	1,484	44,312	1,147	18,872	1,071	16,048
340	2,163	62,545	1,792	33,567	1,699	29,897
350	2,788	87,299	2,385	54,450	2,278	49,786

Reservoir Lands

A reservoir with maximum normal water surface at elevation 336 feet would have storage capacity of 23,700 acre-feet with a dam at Mission Gorge No. Zero site, and 29,200 acre-feet with a dam at Mission Gorge No. 2 site. A capacity of 29,200 acre-feet would be obtained from Mission Gorge Dam No. 3 with water surface at elevation 316 feet. Corresponding elevations of dam crests in the cases of the two maximum water levels would be 353 and 331 feet, respectively. If it be assumed that land would have to be acquired to elevations of the crests of dams, purchase of 2,268 acres would be required for the foregoing Mission Gorge No. Zero and No. 2 reservoirs, and 1,202 acres for Mission Gorge Reservoir No. 3.

As was demonstrated in Bulletin No. 48, cost of reservoir lands for Mission Gorge No. 2 and No. 3 reservoirs would be a considerable portion of total reservoir costs. Estimated rights of way costs in Bulletin No. 48 were based upon 1929 appraised values as determined by Tax Factors, Incorporated. For the current investigation, costs of land acquisition were estimated by B. A. Etcheverry and G. F. Mellin, consultants, whose report is included in Appendix C. The estimates correspond with 1947 values and were derived by a method similar to that described for Lake Hodges in Chapter VII of this report. The following factors were applied to 1946 assessed valuations in order to convert them to 1947 market values:

Type of Property	Factor
Unimproved farm land	4
Improved property	
land	4
improvements	6
Scripps and Good ranches	
land	4
improvements (mostly	5
farm buildings)	

Estimated costs of reservoir lands for Mission Gorge No. Zero and No. 2 reservoirs include cost of a levee to protect improvements on the San Diego County Farm. A summary of estimated rights of way costs is given in Table 49.

TABLE 49

ESTIMATED COSTS OF REQUIRED ADDITIONAL RESERVOIR LANDS
FOR MISSION GORGE RESERVOIRS

(Based on 1947 Market Values)

	Mission Gorge Reservoir	
	No. 2 and No. Zero	No. 3
Elevation up to which land would be acquired, in feet	353	331
Area flooded (excluding presently city-owned land), in acres	2,161	1,163
Area to be acquired (excluding presently city-owned land), in acres	2,268	1,202
ESTIMATED COSTS		
Land	$ 247,000	$ 58,700
Improvements	551,500	127,600
Damages	113,200	24,900
TOTALS	$ 911,700	$ 211,200
Estimated 1935 costs based on 1929 market values	$ 600,000	$ 180,000

Costs of reservoir lands for Mission Gorge reservoirs No. Zero and No. 2 might be reduced by acquiring title in fee only up to some elevation lower than crests of the dams, and securing flowage easements on remaining higher properties. In Bulletin No. 48

it was developed that probable crest flood flows at Mission Gorge No. 2 dam site, with complete conservation development of San Diego River, would be as follows:

	Probable crest flood flow occurring, on average			
	Once in 25 years	Once in 50 years	Once in 100 years	Once in 250 years
Crest flood flow, in second-feet	0	16,200	33,100	50,100
Corresponding reservoir water surface elevation, in feet	336.0	340.6	343.3	345.7

This assumes a 500-foot length of spillway at elevation 336 feet, with weir coefficient of 3.33. In view of the foregoing, it might be considered sufficient to secure title to farm land up to about elevation 341 feet, and flowage rights between that level and elevation 353 feet. It would not be advisable to permit dwellings below elevation 350 feet.

Cost Estimates

In Bulletin No. 48, estimates of cost were presented for reservoirs at Mission Gorge No. 2 and No. 3 sites, both reservoirs involving concrete gravity dams with fixed-crest overflow spillways. Cost estimates for similar reservoirs have been made during the present investigation, but with costs revised to correspond to construction and rights of way prices prevailing in April 1947. In addition, estimates have been prepared, on the basis of April 1947 prices, for a reservoir with a concrete variable-radius arch dam at the No. 3 site, and for one with a combined concrete gravity and rolled earth-fill dam at the Mission Gorge No. Zero site, both dams having spillways of the fixed-crest overflow type.

Since publication of Bulletin No. 48 in 1935, general construction costs have increased from 80 to 100 per cent, but for some items, including heavy excavation and mass concrete, the increased cost has been somewhat less, amounting to from 50 to 60 per cent. During the same period prevailing interest rates have declined from the five per cent figure utilized in Bulletin No. 48 to an estimated three per cent for the current studies, so that annual costs of financing a given project have not increased in proportion to the rise in capital costs. Although estimated 1947 capital cost of Mission Gorge Reservoir No. 2 as presented herein is 68 per cent greater than the estimate for 1935, annual costs for this project increased only nine per cent in the same period.

The greater proportion of increased costs for the 1947 estimates is reflected in major items of concrete, relocation of roads and pipe line, and lands and improvements. Cost of concrete is based upon obtaining aggregates and hauling them from commercial sources along San Diego River. Cost of relocating a county road is based upon a 30-foot wide roadbed in sidehill locations and a 36-foot wide roadbed in flat terrain. The relocated road is provided with a 22-foot width of asphaltic pavement. Cost of relocating a 36-inch diameter pipe line assumes replacement of the existing steel line with concrete-cylinder pipe. However, some saving over this might be effected by salvaging and re-laying the existing pipe.

Costs of pumping water from Mission Gorge reservoirs to the city distribution system are not included in the estimates. The City tentatively plans that water would be

pumped easterly through the existing El Capitan Pipe Line to Santee, to a hydraulic grade line elevation of about 575 feet. From this point it would flow through the existing El Monte Pipe Line to the new Alvarado Treatment Plant adjacent to Murray Reservoir. In the cases of Mission Gorge reservoirs Nos. Zero and 2, average pumping lift would be about 330 feet, whereas in the case of Mission Gorge Reservoir No. 3 it would be approximately 350 feet.

The estimates include allowances of ten per cent for administration and engineering, 15 per cent for contingencies on construction items, and three per cent interest on capital investment during one-half the estimated construction period. Annual costs include interest at three per cent per annum, amortization over a 50-year period, depreciation of dams on the basis of 100-year life and of outlet works on the basis of 50-year life, and operation and maintenance charges.

Mission Gorge Reservoir No. Zero

A cost estimate was made for a dam and reservoir at Mission Gorge No. Zero site having maximum storage capacity of 23,700 acre-feet, with water surface at elevation 336 feet. The estimate is based on a concrete gravity section 860 feet in length across the river channel, with an additional 600 lineal feet of rolled earth fill extending from the right end of the concrete structure to high ground on the right abutment. The concrete gravity dam section used in the estimate is 75 feet in height from streambed to top of non-overflow abutments, or 58 feet from streambed to spillway crest. It has a vertical upstream face, while the downstream face has a slope of 0.8 horizontal to 1.0 vertical, and intersects the upstream face at elevation 353 feet, the crest of the non-overflow portion. The estimate includes provision for a concrete cutoff at the upstream edge, extending ten feet below the general level of the dam foundation. The non-overflow portion of the gravity dam has a crest width of 15 feet.

The reservoir spillway consists of 515 lineal feet of ogee overflow section, centered above the channel, in the concrete gravity portion of the dam. After deducting 15 feet for a gate pier, net length is 500 feet. Crest of the spillway is at an elevation of 336 feet, and its discharge capacity with reservoir water surface at elevation 353 feet is 116,500 second-feet. A concrete bucket is provided at the toe, to deflect the spill and reduce streambed erosion. Streambed at the site is approximately 250 feet wide, and it is assumed that the spillway bucket will be sloped transversely on either side of the channel, to fit the general slope of the foundation rock.

No exploration was made of the foundation at this site. Visual inspection of the site, and of exposed rock at Old Mission Dam, indicates that suitable foundation will be found for any type of dam of moderate height. However, no definite decision to utilize Mission Gorge No. Zero site for a dam should be made without systematic exploration. For purposes of the estimate, required stripping is assumed to be to a depth of 20 feet for the concrete structure, and to a depth of five feet for the rolled earth fill.

A relatively flat bench occurs along the right abutment at the site, above ground surface elevation 325 feet. This is the location of the rolled earth fill, with crest width of 30 feet, and side slopes of three horizontal to one vertical. Crest of the earth fill is at elevation 358 feet, and it laps and imbeds the crest of the concrete section for a distance of 100 feet.

The cost estimate includes provision for two water supply outlets and one emergency, or sluice outlet. Each outlet consists of a 30-inch diameter steel pipe imbedded in concrete of the dam, and controlled by a 30-inch slide valve located in a chamber. Center of the inlet of the pipes is at elevation 285 feet, or seven feet above streambed. Trash racks are located around a semi-circular concrete shaft built on the upstream face of the dam, and extending from the foundation up to the dam crest. Facilities for removal of trash racks and emergency gates consist of a hoist located on a pier constructed on the overflow section at the downstream side of the semi-circular shaft. Access to pier and hoist house is through a gallery constructed into the dam.

The cost estimate includes charges for relocating 3.9 miles of county road, and an equal length of 36-inch diameter pipe line within the reservoir area.

Based upon prices prevailing in April 1947, it is estimated that Mission Gorge Reservoir No. Zero will cost $3,237,500, while annual costs are estimated at $136,100. Detailed estimates of capital and annual costs are given in Appendix H. Layout of the dam is shown on Plate XXII, "Mission Gorge No. Zero Dam on San Diego River".

A concrete gravity main structure, with rolled earth fill on the right abutment, provides a relatively simple layout for a dam at the Mission Gorge No. Zero site, and is comparable to the type of structures used for cost estimates in Bulletin No. 48 for dams at Mission Gorge No. 2 and No. 3 sites. However, cost estimates were also made for major items of a reinforced-concrete slab and buttress dam, and for a combination rock and earth fill structure. It is indicated that the slab and buttress design would cost about the same as the concrete gravity structure. A rock-earth-fill barrier would probably cost less than the concrete gravity dam, but the advantage would be largely offset by additional costs of spillway weir and outlet tower.

Mission Gorge Reservoir No. 2

It was concluded in Bulletin No. 48 that the most economical plan for complete conservation of the water resources of the San Diego River Basin would include a reservoir at the Mission Gorge No. 2 site of 29,200 acre-foot capacity. The dam, upon which cost estimates for a reservoir of this capacity were based, consisted of a concrete gravity section with fixed-crest overflow spillway. The dam was 109 feet in height from streambed to top of non-overflow abutments, or about 92 feet in height from streambed to spillway crest. The upstream face of the dam section was vertical, while the downstream face had a slope of 0.807 to 1, and intersected the upstream face at elevation 353 feet, the crest of the non-overflow portion. Crest width of abutments was ten feet, and their downstream faces were vertical to their intersection with the downstream slope of the dam.

The reservoir spillway, 510 feet in length, and with ogee overflow section, occupied the greater part of the length of the dam. With spillway crest 17 feet below that of the dam, the estimated peak flow from a flood which might occur once in 1,000 years, on the average, would pass over the spillway without overtopping the abutment portions. Along the downstream toe of the dam, at the stream channel, a 300-foot length of concrete bucket section was provided. Concrete-lined channels along the toe of the dam were designed to collect waters from extremities of the spillway and discharge them into the stream channel over the bucket section.

Service outlets consisted of two 30-inch diameter steel pipes at elevation 250 feet, imbedded in concrete of the dam and connecting with a delivery line leading from the

PLATE XXII

PLAN

ELEVATION LOOKING UPSTREAM

SECTION B-B

SECTION A-A
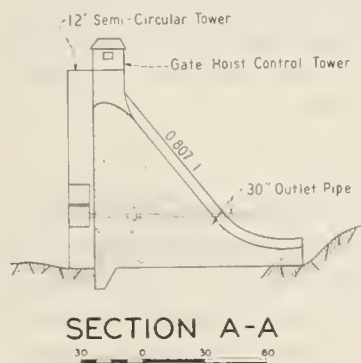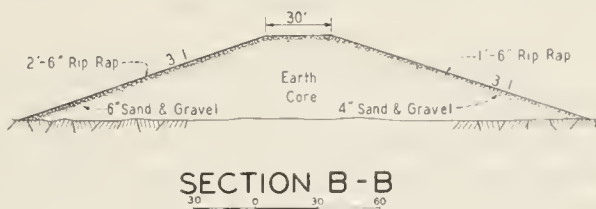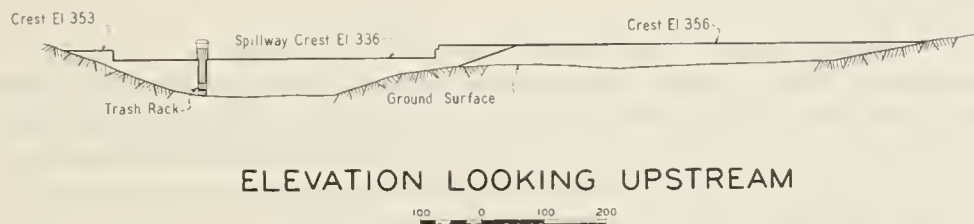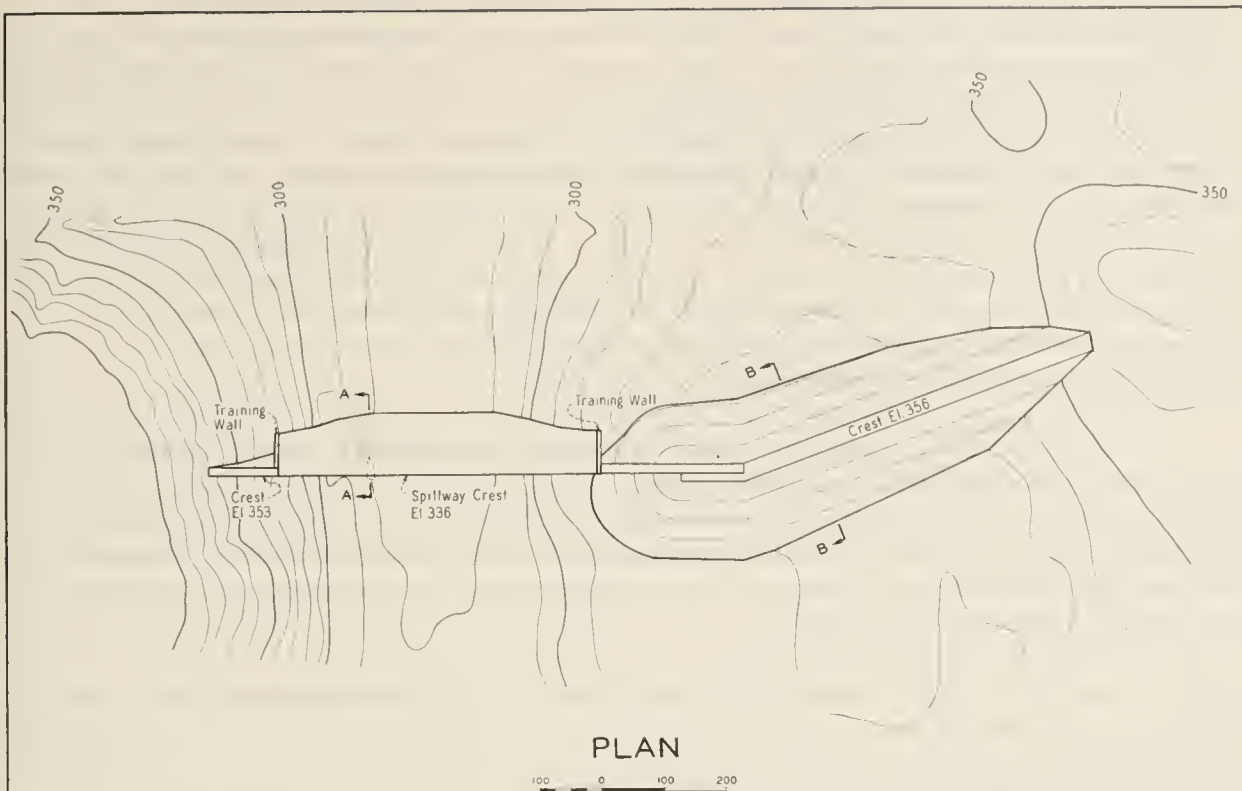
MISSION GORGE NO. ZERO DAM
ON
SAN DIEGO RIVER

SCALES AS SHOWN

reservoir. Control of flow in each pipe was provided by 30-inch diameter slide valves located in a chamber, access to which was from a gallery running through the dam. Upstream from the valve in one of the service outlets, a 30-inch diameter pipe branched out to provide a sluiceway. This line, likewise provided with a slide valve, extended through the dam and discharged into the spillway bucket. The plan included a semi-circular concrete gate tower, 12 feet in outside diameter, on the upstream face of the dam. The tower extended from the foundation line to the top of a pier located on the spillway crest, and was surmounted by a circular gate house. Control of water entering the tower was by means of three 30-inch diameter slide valves operated from the gate house, one located opposite the outlet pipes, and the other two at the one-third points between the lowest valve and the spillway crest. A semi-circular trash rack, raised by a hoist in the gate house, was provided for protection of the gates.

Geology of the dam site was studied by Chester Marliave, geologist, whose report thereon was quoted in Bulletin No. 48. He was aided by information from drill holes and test pits, furnished by the City of San Diego. It is indicated that the site is suitable for construction of a concrete gravity dam and spillway as described herein. However, further exploration and study of foundation conditions should be made prior to entry into a construction program at the site.

Based upon prices prevailing in April 1947, it is estimated that capital cost of Mission Gorge Reservoir No. 2, with 29,200 acre-foot capacity, and with dam and appurtenances as described in Bulletin No. 48, is $3,586,100, and that annual costs are $150,000. Corresponding estimates of 1935 costs, as published in Bulletin No. 48, were $2,142,700 and $137,800, respectively. A detailed estimate of 1947 capital and annual costs is given in Appendix H.

Mission Gorge Reservoir No. 3 with Concrete Gravity Dam

In Bulletin No. 48 a cost estimate was presented for a reservoir of 29,200 acre-foot capacity at the Mission Gorge No. 3 site, the concrete gravity dam being located at the so-called "lower" site. The dam was 231 feet in height from streambed to top of non-overflow abutments, or 216 feet from streambed to spillway crest. The upstream face of the dam section was vertical, while the downstream face had a slope of 0.807 to 1, and intersected the upstream face at elevation 331 feet, the crest of the non-overflow portion. Crest width of abutments was ten feet, and their downstream faces were vertical to their intersection with the downstream slope of the dam.

The reservoir spillway, 650 feet in length, and with ogee overflow section, occupied the greater part of the length of the dam. With spillway crest 15 feet below that of the dam, the estimated peak flow from a flood which might occur once in 1,000 years, on the average, would pass over the spillway without overtopping the abutment portions. Along the downstream toe of the dam, at the stream channel, a 150-foot length of concrete bucket section was provided. Concrete-lined channels along the toe of the dam were designed to collect water from extremities of the spillway and discharge them into the stream channel over the bucket section.

Service outlets consisted of two 30-inch diameter steel pipes at elevation 110 feet, imbedded in concrete of the dam and connecting with a delivery line leading from the reservoir. A third 30-inch diameter pipe line, running through the dam and discharging into the spillway bucket, comprised the sluiceway. Control of flow in each pipe was provided by 30-inch diameter slide valves located in a chamber, access to which was from a

gallery running through the dam. The plan included a semi-circular gate tower, 20 feet in outside diameter, on the upstream face of the dam. The tower extended from the foundation line to the top of a pier located on the spillway crest. The pier was surmounted by a circular gate house. Control of water entering the tower was by means of five 30-inch diameter circular slide valves, operated from the gate house, one located opposite the outlet pipes and the other four at the one-fifth points between the lowest valve and the spillway crest. A semi-circular trash rack, raised by a hoist in the gate house, was provided for the protection of the gates.

Geology of the dam site was studied by Chester Marliave, geologist, whose report thereon was quoted in Bulletin No. 48. He was aided by information obtained from earlier explorations, including data from test holes and pits at the upstream No. 3 site. It is indicated that the lower site is suitable for construction of a concrete gravity dam and spillway as described herein. However, further exploration and study of foundation conditions should be made prior to entry into a construction program at the site.

Based upon prices prevailing in April 1947, it is estimated that capital cost of Mission Gorge Reservoir No. 3, with 29,200 acre-foot capacity and with concrete gravity dam and appurtenances as described in Bulletin No. 48, is $6,157,200, and that annual costs are $259,000. Corresponding estimates of 1935 cost, as published in Bulletin No. 48, were $3,665,600 and $237,100, respectively. A detailed estimate of 1947 capital and annual costs is given in Appendix H.

Mission Gorge Reservoir No. 3 with Concrete Arch Dam

In an effort to determine the most economical solution to the problem of a dam at Mission Gorge No. 3 site, a preliminary design and cost estimate were made for a variable-radius arch dam with fixed-crest overflow spillway at the lower site. Geology of the dam site was studied by Chester Marliave, geologist, who was aided by information obtained from earlier explorations, including data from test holes and pits at the nearby "upper" site. That foundation conditions are not favorable for an arch design is apparent from the following quotations from his report:

"Conditions for concrete arch construction are not as favorable on the abutments as for gravity loading.

"From a geological viewpoint the present topographical features are not inducive for an arch dam. The system of fracturing exemplified in shear zone "C" on the right abutment offers a very unfavorable attitude for this abutment to resist arch thrust.

"The preparation of the abutments for an arch dam at this site would involve a large amount of excavation which the writer believes would be economically prohibitive.

"As there are serious geological problems to be contended with in consideration of each type or new location for a dam in this locality it is of paramount importance that recognition be given to structural and physical conditions of the abutments in the design of any dam in this portion of the gorge."

From the standpoint of topography, the site is not ideal for an arch dam, since the slope of the canyon walls is flatter than desirable and the contours are parallel with the thread of the stream. However, it is seldom that a site can be found with favorable convergence of contours in a downstream direction, and this adverse condition at the Mission Gorge No. 3 site might be overcome by heavy excavation.

Height of the arch dam, like that of the gravity structure considered for the same site, is 216 feet from streambed to spillway crest at elevation 316 feet. The dam is designed in accordance with a formula providing for gradual thickening of the arch from crown to abutments, thus providing for a practically equal intensity of stresses at the crown and the abutments. Gravity abutments at the ends of the upper portions of the arch provide for thrust, which otherwise would not be satisfactorily transmitted to the hillsides. Overall length of the dam at spillway crest elevation is 961 feet, and of the arch proper 811 feet. The gravity section on the right abutment is 90 feet in length, while that on the left abutment is 60 feet in length.

The plan provides for a sliding joint at elevation 120 feet, the dam below this elevation being designed to support the water load by gravity action, although arch action will add appreciably to its stability. Were it not for this provision, the probable abrupt change in profile at this elevation, after excavation has been completed, might cause severe localized stresses in the arch.

In order to minimize tension in the abutments, the arch layout was made with central angles of 120 degrees or larger. This is the minimum angle without resultant tension for a value of thickness divided by radius of 0.2. With a similar ratio of 0.3, the required central angle is 140 degrees.

Excavation is assumed on the basis of radial contact at the abutments, and a depth to sound rock of 20 feet at the intrados. If it is found necessary to excavate to a greater depth at this point, a variation of ten degrees from radial is permissable, which would amount to about seven feet for an abutment thickness of 40 feet.

The reservoir spillway consists of 625 lineal feet of ogee overflow section centered above the channel, with training walls five feet in thickness at either end. Discharge capacity with reservoir water surface at elevation 331 feet, the crest of the non-overflow abutments, is about 131,000 second-feet. The estimate includes provision for a concrete slab apron, ten feet thick below elevation 160 feet, and varied in thickness above that elevation to four feet near the top. Streambed at the site is approximately 160 feet wide, and it is assumed that the apron is sloped transversely at either side of the channel to fit the general slope of the foundation rock. The apron parapet wall is ten feet in thickness at the base, and five feet at the crest. No reinforcing steel is provided for the apron, or apron parapet and curtain walls, the structures being considered sufficiently massive to accomplish their purposes without reinforcement. While a parapet wall on the apron is included in the estimate, final design might prove this feature to be desirable only on the sloping portions above tail water level. In its lower portions, the wall may tend to produce eddies in a vertical plane, causing more undercutting at the toe than would be the case if the water flowed freely in a horizontal direction off the flat unobstructed floor.

Outlet works include a 36-inch diameter steel pipe manifold, mounted on the upstream face of the dam and encased in reinforced concrete. Five 30-inch diameter inlet valves are spaced at equal increments of elevation on the manifold. These gates are protected by steel trash racks, and are operated by hydraulic cylinder controls from a gate house located on top of the gravity thrust section at the left abutment. The manifold extends downstream in a concrete-filled trench beneath the dam and apron, from where it leads to the service main, being controlled by a gate valve.

Based upon prices prevailing in April 1947, it is estimated the capital cost of Mission Gorge Reservoir No. 3, with 29,200 acre-foot capacity and with a variable-radius concrete arch dam at the lower site, is $5,241,900, and that annual costs are $220,000. A detailed estimate of 1947 capital and annual costs is given in Appendix H. Layout of the dam is shown on Plate XXIII, "Variable-Radius Arch Dam at Lower Mission Gorge No. 3 Site on San Diego River".

Comparison of Reservoirs

Studies for Bulletin No. 48 indicated that the most desirable storage capacities for the then proposed San Vicente and Mission Gorge reservoirs were 174,500 and 29,200 acre-feet, respectively. Although San Vicente Reservoir was actually built to a capacity of only 90,200 acre-feet, the increment to safe yield of the entire San Diego River system to be derived from a reservoir at Mission Gorge is no different than with a 174,500 acre-foot San Vicente Reservoir. This follows from the fact that during the 1896-1905 critical period no spill would have occurred from either a 90,000 or 174,500 acre-foot San Vicente Reservoir, so that inflow and yield of Mission Gorge reservoirs would have been independent of this source in either case. Additional safe seasonal yields to be derived from construction of Mission Gorge reservoirs Nos. 2 and 3, respectively, under present conditions and with coordinated operation of the entire San Diego River development, are therefore identical with those determined during the Bulletin No. 48 studies. Corresponding yield to be obtained from construction of Mission Gorge Reservoir No. Zero was determined by studies conducted during the current investigation. The increments to total seasonal yield of the San Diego River development resultant from each of the reservoirs considered for Mission Gorge, together with unit costs based on 1947 construction, rights of way and financing prices, are given in Table 50.

TABLE 50

ESTIMATED AMOUNTS AND 1947 COSTS OF ADDITIONAL SAFE YIELD
FROM RESERVOIRS AT MISSION GORGE
WHEN OPERATED COORDINATELY WITH THE EXISTING
SAN DIEGO RIVER DEVELOPMENT

Safe Yield Based on Critical Period
1895-96 to 1904-05, Inclusive

Mission Gorge Reservoir No.	Type of Dam	Storage Capacity in Acre-Feet	Additional Safe Seasonal Yield in Acre-Feet	Annual Costs	
				Reservoir	Safe Yield per Acre-Foot
Zero	Combination concrete gravity and earth fill	23,700	1,900	$136,100	$71.65
2	Concrete gravity	29,200	2,300	150,000	65.20
3	Concrete gravity	29,200	2,600	259,000	99.60
3	Concrete arch	29,200	2,600	220,000	84.60

It is shown in Table 50 that Mission Gorge Reservoir No. Zero is less desirable than a reservoir at the Mission Gorge No. 2 site, both in amount and unit cost of additional safe yield. It is also shown that increases in cost of construction and of reservoir lands have not altered the conclusion reached in Bulletin No. 48 to the effect that Mission Gorge Reservoir No. 2 is more favorable than No. 3. As has been stated, costs of

pumping yield from Mission Gorge reservoirs to the San Diego city distribution system are not included in the foregoing cost estimates. If this item were included, the already high relative cost of yield from Mission Gorge Reservoir No. 3 would be further increased, as compared with that from either Mission Gorge Reservoir No. Zero or No. 2. However, if it should ever be found desirable to provide a recreational lake in Mission Gorge, the fact that the No. 3 site comprises canyon storage with materially lower evaporation losses than upstream sites should be considered. Economic analyses of such dual purpose developments in Mission Gorge, which would involve higher dams to provide storage reservations for recreation as well as necessary conservation, have not been included in the present studies.

Enlarged San Vicente Reservoir

Although the existing San Vicente Reservoir of 90,200 acre-foot capacity is more than adequate to effect complete conservation of runoff from the tributary San Vicente Creek watershed, its enlargement for storage of foreign water may be desirable because of favorable geographical, climatological and storage characteristics of the site.

Water from San Vicente Reservoir can be delivered by gravity to the Alvarado Filtration Plant, from which point about 85 per cent of the City's presently utilized service area can be served by gravity. The reservoir is characterized by small water surface area as related to storage capacity, and in this respect is highly efficient. Furthermore, the site is only rarely subject to hot desert winds, and average net depth of unit evaporation is not excessive, as in the case of reservoirs at higher elevations in San Diego County. The City of San Diego states that San Vicente Reservoir has the least evaporation losses for long-time storage of any of the City's reservoirs.

Officials of the City of San Diego visualize a need for local water storage capacity, in addition to that required for complete conservation of runoff from local water sources. Such a strategically located reserve would provide an emergency supply in case of unprecedented drought, destruction or interruption of the San Diego Aqueduct, or other unforseen disaster. Supplemental storage space in San Vicente Reservoir would also permit transfer of water from the less efficient El Capitan Reservoir, and thereby increase yield of the San Diego River. Water from the proposed Sutherland Reservoir in San Dieguito Basin might likewise be imported to San Vicente Reservoir for regulation and long-time storage.

It has been suggested by officials of the City of San Diego that a San Vicente Reservoir of 250,000 acre-foot capacity would provide 150,000 acre-feet of storage for the combined purposes of conserving San Vicente Creek runoff, storing San Diego River water transferred from El Capitan Reservoir, and storing San Dieguito Basin water imported from Sutherland Reservoir. Under the City's plan, the remaining 100,000 acre-feet of storage capacity in San Vicente Reservoir would be reserved for Colorado River water, an amount in itself sufficient to supply estimated ultimate water requirements of the City for nearly a year.

The present San Vicente Dam is a straight concrete gravity structure, with central overpour spillway ending in a concrete bucket section. It is 190 feet in height to spillway crest above streambed, and has a crest length of 980 feet. The outlet works consist of a semi-circular tower on the upstream face of the dam. At 30-foot increments of

PLATE XXIII
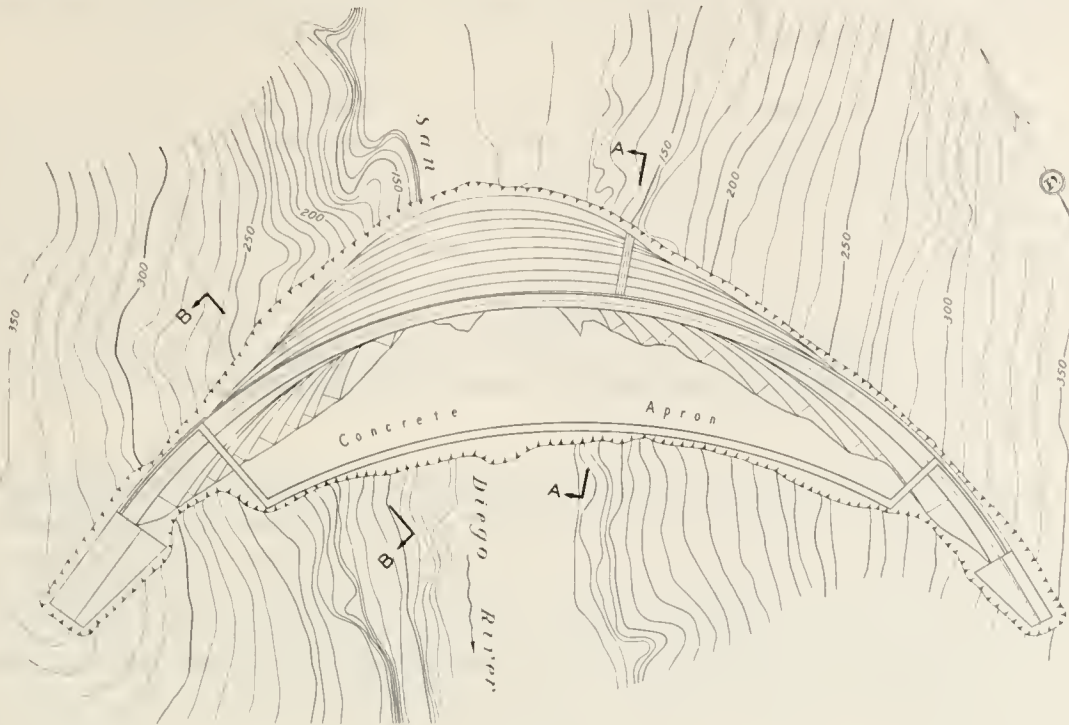
PLAN
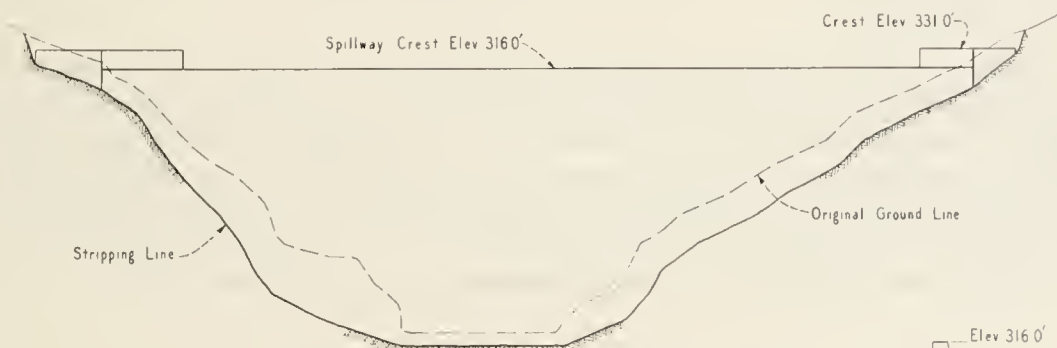
ELEVATION LOOKING UPSTREAM
(GROUND PROFILE ON ℄ OF ARCH RINGS)
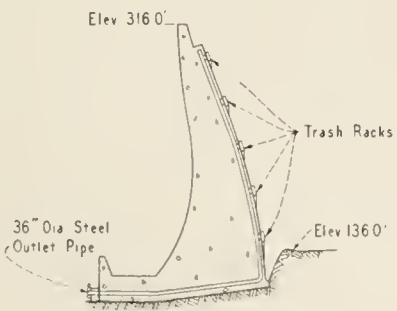
SECTION A-A
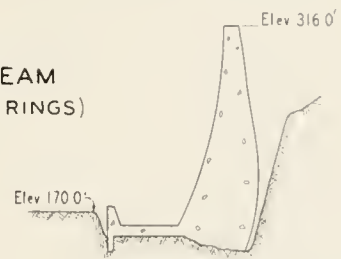
SECTION B-B

VARIABLE RADIUS ARCH DAM
AT
LOWER MISSION GORGE NO. 3 SITE
ON
SAN DIEGO RIVER

SCALE OF FEET
40   0   40   80   120
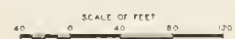
elevation saucer valves are provided, which are operated from a control platform at the
top of the tower. Three 36-inch diameter cast-iron outlet pipes discharge through the dam
from the base of the tower. Two of the outlet pipes are provided with valves at a valve
house at the downstream toe of the dam, and the third is covered by a blind flange.

The dam was constructed with the consideration in mind of raising it to 310 feet
in height at some future date, by adding concrete on the downstream side. Grouting was
carried on to the extent necessary for the higher dam. However, no stepping or other spec-
ial treatment was given to the downstream face. Studies indicate that this condition is
not insurmountable, but that special methods of construction will be required to properly
place the additional concrete on the old surface, and at the same time provide for shrink-
age due to cooling and settling. A further problem presented is that of securing a good
seal at the upstream face between the old structure and the raise. The surface between
the new and old concrete must be thoroughly drained, and inspection galleries must be pro-
vided to permit inspection of such drainage.

The upstream slope of the present San Vicente Dam is battered at a slope of
0.1 to 1 below elevation 600 feet, and at a slope of 0.05 to 1 above that elevation.
The downstream face has a slope of 0.7b to 1. The plan of enlargement upon which cost
estimates for this report are based contemplates making the upstream face of the enlarge-
ment vertical, and battering the downstream face at a slope of 0.8 to 1. Details of
crest, spillway and outlet works would be reconstructed similarly to those now existing.
The outlet tower would be raised by removing the existing operating platform, and then
extending the tower. In order to achieve the desired storage capacity of 250,000 acre-
feet, the crest of the spillway would be raised to elevation 768 feet, or an increase of
118 feet above the present dam. Height of the enlarged dam would be 308 feet to spillway
crest above streambed.

Costs of the present dam, completed in 1943 by the City of San Diego, were ap-
proximately $2,767,000, including costs of rights of way. The City of San Diego now owns
all rights of way required for the enlargement, and no highway or utility relocation
would be involved. Based upon prices prevailing in April 1947, it is estimated that
capital cost of enlarging the existing San Vicente Reservoir to storage capacity of
250,000 acre-feet is $8,489,500, and that annual costs are $352,600. A detailed estimate
of 1947 capital and annual costs of the enlargement is given in Appendix H.

APPENDIX A

AGREEMENTS AUTHORIZING INVESTIGATION AND REPORT

AGREEMENT BETWEEN THE DEPARTMENT OF PUBLIC WORKS OF THE
STATE OF CALIFORNIA
AND THE CITY OF SAN DIEGO FOR INVESTIGATION OF AND REPORT UPON
WATER RESOURCES OF SAN DIEGUITO RIVER

This agreement, executed in triplicate, entered into by and between the Department of Public Works of the State of California, acting by and through the State Engineer, hereinafter referred to as "Department" and the City of San Diego, hereinafter referred to as "City":

W I T N E S S E T H:

WHEREAS, City is desirous of having Department, acting by and through the State Engineer, make an investigation of the water resources of the San Dieguito River in San Diego County and other water resources usable in combination therewith for the purpose of determining the best program of development of a water supply on the San Dieguito River for City and of having Department prepare a written report thereon; and

WHEREAS, City has the sum of Ten Thousand Dollars ($10,000.00) available to match an equal sum to be provided by the State of California for said investigation and report; and

WHEREAS, the State of California has a paramount interest in the use of water and in the protection of the public interest in the development of water resources, and Department, acting by and through the State Engineer, is authorized in the Water Code to cooperate with any city in investigation of any water supply; and

WHEREAS, the Director of Finance of the State of California has made emergency fund allotment promise No. 842, dated October 4, 1944, to the Division of Water Resources of the Department of Public Works, in the sum of Ten Thousand Dollars ($10,000.00) for said investigation and report, which sum is to be matched by a like sum from sources other than the State;

NOW, THEREFORE, in consideration of the premises and of the several promises to be faithfully performed by each as hereinafter set forth, the parties do hereby mutually agree as follows:

ARTICLE I   WORK TO BE PERFORMED

The work to be performed by Department under this agreement shall include but not be limited to the following:

(a) The making, where necessary, of topographic and other field surveys of dam and reservoir sites on the San Dieguito watershed and transmission lines therefrom.

(b) The exploration of dam sites on the San Dieguito River.

(c) Estimates of present and probable maximum future utilization of the water resources in the San Dieguito watershed.

(d) Estimates of water yield both total and additional from San Dieguito watershed with various combinations of reservoirs on that stream with existing and possible future reservoirs of the City of San Diego and with present and possible future development on the San Dieguito watershed.

(e) Estimates of cost of construction of dams and reservoirs for various sites and capacities and of transmission lines therefrom. Estimates of cost of securing necessary water rights under the several conditions are to be made by City at its own expense and submitted to Department.

(f) Other field and office work that may be mutually agreed upon by the parties hereto during the progress of the investigation.

(g) Preparation and submission to City of a written report based upon the studies and investigations outlined herein on or before January 1, 1946, which will contain recommendations and general plans and estimates of cost for a program of development of the water resources of the San Dieguito watershed.

ARTICLE II   FUNDS

City upon execution by it of this agreement shall forward to Department, for expenditure in the performance of said work, the sum of Ten Thousand Dollars ($10,000.00). Said sum shall be deposited in a trust account in the Special Deposit Fund in the State Treasury and thereafter transferred to the Water Resources Fund.

If the Director of Finance within thirty (30) days after receipt by Department of said sum from City shall not have allocated from the Emergency Fund (Stats. 1943, Ch. 62, Item 221), the sum of Ten Thousand Dollars ($10,000.00) to Department for expenditure in the performance of said work, said sum so transmitted shall be returned to City upon demand, if such demand is made after the expiration of said thirty (30) days and prior to the making of said allocation.

Department shall under no circumstances be obligated to expend for or on account of the work provided for under this agreement any sum in excess of the Twenty Thousand Dollars ($20,000.00) as provided for in this agreement, and in the event of inadequacy of funds shall be obligated to make only such investigation and report as funds available therefor shall permit.

Upon completion of and final payment for the work provided for in this agreement Department shall furnish to City a statement of all expenditures made under this agreement and of any expenditures made on account of said work from funds, if any, other than those allocated for said work from said Emergency Fund. If any balance shall remain of the sum of Twenty Thousand Dollars ($20,000.00) as made available as aforesaid, there shall be returned to City one-half of said balance.

ARTICLE III   CONTINGENT UPON ALLOCATION

Notwithstanding anything contained in this agreement contrary hereto or in conflict herewith, this agreement is made contingent upon the Director of Finance making the necessary allocation of funds to Department to meet its share of the cost of said work as provided for in this agreement. This agreement shall become effective only after said allocation is made.

ARTICLE IV   AVAILABILITY OF RECORDS

All data and records pertaining to the work covered by this agreement in the possession or control of City or Department shall be made fully available to the other for the due and proper accomplishment of the purposes and objects hereof.

IN WITNESS WHEREOF, the parties have affixed their signatures and official seals, City on the 1st day of February, 1945, and Department on the 20th day of February, 1945.

Approved:

C. H. PURCELL   THE CITY OF SAN DIEGO
Director of Public Works   (SEAL)
By   A. H. Henderson   By   F. A. Rhodes
       Assistant Director   Acting City Manager

Approved:

     R. M. Dorton
Deputy Director of Finance

Approved: DEPARTMENT OF PUBLIC WORKS OF THE
                                                    STATE OF CALIFORNIA
                                                                     (SEAL)
     J. F. Du Paul
City Attorney of San Diego   By   Edward Hyatt
By B. L. Comparet, Deputy   State Engineer

Approved:

     C. C. Carleton
Chief Attorney, Department
  of Public Works

Approval Recommended:

     Spencer Burroughs
Principal Attorney, Division
  of Water Resources

AGREEMENT BETWEEN THE DEPARTMENT OF PUBLIC WORKS OF
THE STATE OF CALIFORNIA AND THE CITY OF SAN DIEGO
FOR INVESTIGATION OF AND REPORT UPON WATER RESOURCES
OF THE SAN DIEGUITO RIVER AND THE SAN DIEGO RIVER.

Superseding Former Agreement Limited to
Investigation of and Report Upon the Water
Resources of San Dieguito River.

This agreement, executed in triplicate, entered into by and between the Department of Public Works of the State of California, acting by and through the State Engineer, hereinafter referred to as "Department" and the City of San Diego, hereinafter referred to as "City",

W I T N E S S E T H:

WHEREAS, City is desirous of having Department, acting by and through the State Engineer, make an investigation of the water resources of the San Dieguito River and of the San Diego River in San Diego County and other water resources usable in combination therewith for the purpose of determining the best program of development of a water supply on the San Dieguito and on the San Diego rivers for City and of having Department prepare a written report thereo ; and

WHEREAS, under an agreement heretofore entered into by and between the parties hereto, executed by City on February 1, 1945, and by Department on February 20, 1945, an investigation has been commenced of the water resources of the San Dieguito River and the total sum of Twenty Thousand Dollars ($20,000.00) has been made available for said investigation and a report thereon, Ten Thousand Dollars ($10,000.00) by each party; and

WHEREAS, it is now the desire of each party that an additional sum of Twenty Thousand Dollars ($20,000.00) shall be provided, Ten Thousand Dollars ($10,000.00) by each party; that said investigation and report to be made thereafter shall include the San Diego River as well as the San Dieguito River; and that said investigation as enlarged shall continue and terminate in a report upon both rivers, the same as if the previous agreement had provided for a total sum of Forty Thousand Dollars ($40,000.00), one-half from each party, for investigation and report upon both rivers; and

WHEREAS, the State of California has a paramount interest in the use of water and in the protection of the public interest in the development of water resources, and Department, acting by and through the State Engineer is authorized in the Water Code to cooperate with any city in investigation of any water supply;

NOW THEREFORE, in consideration of the premises and of the several promises to be faithfully performed by each as hereinafter set forth, the parties do hereby mutually agree as follows:

ARTICLE I   WORK TO BE PERFORMED

The work to be performed by Department under this superseding agreement shall include but not be limited to the following:

(a) The making, where necessary, of topographic and other field surveys of dam and reservoir sites on the San Dieguito and the San Diego watersheds and transmission lines therefrom.

(b) The exploration of dam sites on the San Dieguito and the San Diego rivers.

(c) Estimates of present and probable maximum future utilization of the water resources in the San Dieguito and San Diego watersheds.

(d) Estimates of water yield both total and additional from San Dieguito and San Diego watersheds with various combinations of reservoirs on those streams with existing and possible future reservoirs of the City of San Diego and with present and possible future development on the San Dieguito and San Diego watersheds.

(e) Estimates of cost of construction of dams and reservoirs for various sites and capacities and of transmission lines therefrom. Estimates of cost of

securing necessary water rights under the several conditions are to be made by City at its own expense and submitted to Department.

(f) Other field and office work that may be mutually agreed upon by the parties hereto during the progress of the investigation.

(g) Preparation and submission to City of a written report based upon the studies and investigations outlined herein on or before January 1, 1946, which will contain recommendations and general plans and estimates of cost for a program of development of the water resources of the San Dieguito and San Diego watersheds.

ARTICLE II   FUNDS

City upon execution by it of this superseding agreement shall transmit to Department, for expenditure in the performance of said work, the sum of Ten Thousand Dollars ($10,000.00). Said sum shall be deposited in a trust account in the Special Deposit Fund in the State Treasury and thereafter transferred to the Water Resources Fund.

If the Director of Finance within thirty (30) days after receipt by Department of said sum from City shall not have allocated from the Emergency Fund (Stats. 1943, Ch. 62, Item 221), the sum of Ten Thousand Dollars ($10,000.00) to Department for expenditure in the performance of said work, and within the same period shall not have re-allocated, or otherwise made available, for expenditure for the purpose of this superseding agreement the Ten Thousand Dollars ($10,000.00), or all thereof remaining unexpended, which was previously allocated by Executive Order No. E-1306, dated March 9, 1945, the Ten Thousand Dollars ($10,000.00), transmitted by City upon execution by it of this superseding agreement, shall be returned to City upon demand, if such demand is made after the expiration of said thirty (30) days and prior to the making of said allocation and said re-allocation.

City agrees that the Ten Thousand Dollars ($10,000.00) heretofore forwarded by it and deposited in the State Treasury pursuant to said previous agreement relative to the San Dieguito River, or all thereof remaining unexpended, shall be used in carrying out the enlarged purpose of this superseding agreement.

Both parties agree that expenditures heretofore made and expenses incurred under said previous agreement shall be chargeable against, and payable under, this superseding agreement the same as if this superseding agreement had been in effect from the effective date of said previous agreement and that said previous agreement is hereby superseded by this superseding agreement with the same effect and result as would have been the case had the previous agreement provided for a total expenditure of Forty Thousand Dollars ($40,000.00), one-half from each party, for investigation and report upon both rivers.

Department shall under no circumstances be obligated to expend for or on account of the work provided for under this superseding agreement any sum in excess of the Forty Thousand Dollars ($40,000.00) as provided for in this superseding agreement, and in the event of inadequacy of funds shall be obligated to make only such investigation and report as funds available therefor shall permit.

Upon completion of and final payment for the work provided for in this superseding agreement, Department shall furnish to City a statement of all expenditures made under this superseding agreement and of any expenditures made on account of said work from State funds, if any, other than those allocated for said work from said Emergency Fund. If any balance shall remain of the sum of Forty Thousand Dollars ($40,000.00) as made available as aforesaid, there shall be returned to City one-half of said balance.

ARTICLE III   CONTINGENT UPON ALLOCATION

Notwithstanding anything contained in this superseding agreement contrary hereto or in conflict herewith, this superseding agreement is made contingent upon the Director of Finance making the necessary allocation and re-allocation of funds to Department to meet its share of the cost of said work as provided for in this superseding agreement. This superseding agreement shall become effective only after said allocation and re-allocation is made.

ARTICLE IV   AVAILABILITY OF RECORDS

All data and records pertaining to the work covered by this superseding agreement in the possession or control of City or Department shall be made fully available to the other for the due and proper accomplishment of the purposes and objects hereof.

IN WITNESS WHEREOF, the parties have affixed their signatures and official seals, City on the 1st day of May, 1945, and Department on the 11th day of May, 1945.

Approved:

/s/ C. H. PURCELL   THE CITY OF SAN DIEGO

Director of Public Works   (SEAL)

                                            By   F. A. Rhodes
                                                    City Manager

Approved:

    James S. Dean
Director of Finance

Approved: DEPARTMENT OF PUBLIC WORKS
                                            OF THE STATE OF CALIFORNIA
    J. F. DuPaul
City Attorney of San Diego   (SEAL)

Approved: By   Edward Hyatt
                                                    State Engineer
    C. C. Carleton
Chief Attorney, Department of
    Public Works

Approval Recommended:

    Spencer Burroughs
Principal Attorney, Division
    of Water Resources

SUPPLEMENTAL AND AMENDATORY AGREEMENT BETWEEN THE
STATE DEPARTMENT OF PUBLIC WORKS AND THE CITY OF
SAN DIEGO FOR THE INVESTIGATION OF AND REPORT UPON
WATER RESOURCES OF THE SAN DIEGUITO RIVER AND THE
SAN DIEGO RIVER.

        This agreement, executed in triplicate, entered into by and between the Department of Public Works of the State of California, acting by and through the State Engineer, hereinafter referred to as "Department" and the City of San Diego, hereinafter referred to as "City",

                            W I T N E S S E T H:

        WHEREAS, by agreement heretofore entered into by and between the parties hereto, executed by City on the 1st day of May, 1945, and by Department on the 11th day of May, 1945, the making by Department of an investigation of the water resources of the San Dieguito River and of the San Diego River and rendering a report thereon was provided for; and

        WHEREAS, additional funds are required to complete said investigation and report, and it is the desire of each party that an additional sum of Twenty-Five Thousand Dollars ($25,000.00) shall be provided, Twelve Thousand Five Hundred Dollars ($12,500.00) by each party;

        NOW THEREFORE, in consideration of the premises and of the several promises to be faithfully performed by each as hereinafter set forth, the parties do hereby mutually agree as follows:

        1. City upon execution by it of this agreement shall forward to the Department the sum of Twelve Thousand Five Hundred Dollars ($12,500.00) which shall be deposited in the Water Resources Fund (also known as the Water Resources Revolving Fund) in the State Treasury for expenditure by Department for the making of an investigation of the water resources of the San Dieguito River and of the San Diego River and rendering a report thereon.

2. Upon receipt of said sum of Twelve Thousand Five Hundred Dollars ($12,500.00) from City and deposit thereof into said fund, Department shall procure the deposit into said fund of state funds in equal amount which have been made available by Executive Order No. E-1974 dated March 26, 1947, of Department of Finance.

3. Insofar as consistent herewith, all of the terms and provisions of said prior agreement to which this agreement is supplemental and amendatory are hereby confirmed, ratified and continued in effect.

IN WITNESS WHEREOF, the parties hereto have affixed their signatures and official seals, City on the 24th day of April, 1947, and Department on the 1st day of May, 1947.

Approved:

C. H. PURCELL

Director of Public Works   (SEAL)

By   A. H. Henderson
          Deputy Director

Approved:

          James S. Dean
Director of Finance

Approved:

_____
City Attorney of San Diego

Approved:

          C. C. Carleton
Chief Attorney, Department of
Public Works

Approval Recommended:

          Spencer Burroughs
Principal Attorney, Division
   of Water Resources

THE CITY OF SAN DIEGO

By   F. A. Rhodes
             City Manager

DEPARTMENT OF PUBLIC WORKS
OF THE STATE OF CALIFORNIA

By   A. D. Edmonston
             Assistant State Engineer

LJH
DEPARTMENT OF FINANCE
APPROVED
May 5, 1947

APPENDIX B

ESTIMATES OF COST OF ACQUISITION
OF WATER RIGHTS
REQUIRED FOR DEVELOPMENT OF SAN DIEGUITO BASIN
.

By
G. E. Arnold, Director of Water Department,
The City of San Diego

April 22, 1948

THE CITY OF SAN DIEGO
San Diego 1, California

April 22, 1948

Edward Hyatt, State Engineer
401 Public Works Building
Sacramento 5, California

Attention: A. D. Edmonston
Deputy State Engineer

Dear Sir:

The State Engineer in draft of a letter to City Manager dated Dec. 19, 1947 prepared for preliminary discussion indicated that the City should, in accordance with contract under which investigations are being made, furnish estimated costs of certain water rights.

A review has been made of the water rights obtained by the City's predecessors downstream from Hodges Dam. It is indicated that with full conservation of the runoff occurring above Hodges Reservoir by construction of Sutherland, Pamo and Super-Hodges Dams, $35,000 may be required to quiet legitimate claims from interference with water rights below Hodges Dam caused by the additional storage of water.

A brief review has been made of the sources and dependability of the water supply of certain lands in Sections 23, 25, 26, 35, and 36, T. 12 S, R. 1 W, being that portion of San Pasqual Valley and the surrounding hills easterly of the Fenton lands.

It is indicated that the total value of the property approaches $500,000.

(a) If either or both Sutherland and Pamo reservoirs were constructed and operated to capacities of 36,500 and 47,500 acre feet, respectively, and only runoff that would be of no value to the lands in question were placed in storage and diverted to San Vicente reservoir, then it is deemed reasonable to suppose that there could be no legitimate claims against the City. In fact the lands would be substantially benefitted because of the material reduction in damage from floods.

(b) If both Sutherland and Pamo reservoirs were constructed and operated to capacities of 36,500 and 47,500 acre feet, respectively, and the maximum quantities of water impounded and diverted to San Vicente reservoir, it is deemed reasonable to suppose that the acquisition of the necessary water rights would cost about $400,000.

(c) If Sutherland reservoir were constructed and operated to a capacity of 36,500 acre feet and the maximum quantity of water impounded and diverted to San Vicente reservoir, it is deemed reasonable to suppose the acquisition of the necessary water rights would cost $250,000.

Very truly yours,

/s/ G. E. Arnold

G. E. Arnold
Director, Water Department

FDP/f

APPENDIX C

ESTIMATES OF COST OF LAND ACQUISITION

FOR LAKE HODGES AND MISSION GORGE RESERVOIRS

By

B. A. Etcheverry, Consulting Civil Engineer
and
G. F. Mellin, Consulting Land Appraiser

B. A. ETCHEVERRY
Consulting Civil Engineer

12 Engineering Building
Berkeley

April 29, 1947

Mr. Edward Hyatt, State Engineer   Subject: Cost of Lands for
401 Public Works Building   Super-Hodges
Sacramento 5, California   Reservoir

Dear Sir:

At your request we have estimated the present day market value of the lands and
improvements in the proposed Super-Hodges Reservoir that would have to be purchased, and
of the accompanying damages, for each of the four different water surface elevations that
have been considered or proposed. We herewith submit a brief statement of the work done
and a summary of our findings.

For our work we had: (1) a good contour map of the reservoirs lands on which
was transposed the property ownerships and soil types; (2) the Fairchild Aerial maps on
which were shown the proposed highwater lines and the boundaries of properties affected;
(3) the basic data on the properties that would have to be purchased. This basic data
included the descriptions and acreages of the properties, the county assessor's data for
1946 valuations, and the information on sales of properties in the proposed reservoir.
In addition we had sales of other properties not in the reservoir but in the general
vicinity.

The County Assessor's information and data on each property is complete and de-
pendable. It contains detailed data on all of the improvements. This information and
data is far superior to that of any other County with which we are acquainted.

We made an analysis of the sales made since 1941 and compared the sales values
with the corresponding 1946 County Assessor's valuations. We used the 1946 County Asses-
sor's valuations because these were available for all the properties in the reservoir,
while the 1947 valuations had not been completed for all the properties. From this com-
parison of sales values with the corresponding 1946 County valuations, and with allowance
for the increase in market values from the dates of the sales to the present we concluded
that a very good estimate of the present day market values of all the properties involved
could be obtained by using the following factors or ratios of market value to 1946 County
Assessor's valuations - a factor of 5 for all farm properties (including lands and im-
provements) and a factor of 6 for all subdivision property in Campo Del Dios. For the
few properties on which improvements were made since 1946 County Assessor's valuation we
made separate estimates of the value of these improvements.

With all of this information and data, and the dependable ratio of market value
to County Assessor's valuations it was possible to complete our work in the field in the
three days, April 10, 11, and 12 that we were in San Diego, and to make our estimate of
present day market values in a relatively short time.

Our findings of the total present day market value of all the lands and improve-
ments to be purchased including the accompanying damages and the cost of relocating the
power and telephone circuits for each of the four proposed water surface elevations are
summarized in the following tabulation.

	Elevation of Water Surface			
	368	382	396	416
Acres to be flooded (excluding city owned)	717	1,316	2,003	3,216
Acres to be purchased (excluding city owned)	1,222	2,422	4,148	4,871
Estimated Cost of: Lands	$ 381,420	$ 565,230	$ 846,600	$ 904,240
Improvements	547,040	584,190	752,960	785,690
Damages	96,870	202,700	115,600	120,550
TOTAL	$1,025,330	$1,352,120	$1,715,160	$1,810,480

We attach as part of this Report the accompanying statement of Procedure followed in estimating the right-of-way costs for Super-Hodges Reservoir, including a tabulation of the main items of costs.

Mr. D. B. Willets collected and compiled in excellent shape the information and data used by us, he accompanied us on our trip to San Diego and gave us the benefit of his knowledge of local conditions. He made all the required computations in accordance with our instructions. His efficient and competent help is appreciated.

Respectfully submitted,

/s/ B. A. Etcheverry
     B. A. Etcheverry

/s/ G. F. Mellin
     G. F. Mellin

Enclosure:

PROCEDURE FOLLOWED IN ESTIMATING RIGHT OF WAY COSTS FOR SUPER-HODGES RESERVOIRS

April 25, 1947

Right of way costs were estimated for four different water surface elevations -

Max. W.S. Elevation U.S.G.S. datum	Height, Dam to Spillway Feet	Reservoir Capacity Acre-Feet	Safe Yield Acre-Feet
368	150	104,464	20,200
382	165	157,300	24,000
396	180	224,800	26,800
416	200	340,000	29,300

Basic data on property owners, property descriptions, assessed valuations, and recent sales were secured in the San Diego County Assessor's office.

The Hodges Reservoir area for the purpose of the right of way study was divided into two general areas. All of the lands east of the westerly line of Rancho San Bernardo and comprising the Bernardo Region and San Pasqual Valley are shown on Fairchild Aerial map four inches to the mile. All of the remainder, being west of the westerly line of Rancho San Bernardo and including the Campo Del Dios Subdivision, is shown on a Fairchild Aerial map one inch to 400 feet. On these maps property lines are shown in blue and the limits of San Diego City ownership are defined in red. Property is identified by a D.W.R. reference number. On the first mentioned map (4 inches to the mile) soil classifications have been imposed as well as data respecting recent property sales. On both maps the contours of the four proposed high water lines, elevations 368, 382, 396 and 416 are shown. For each parcel of property the flooded area at each of the four elevations was determined by planimeter.

A complete tabulation of all the property owners whose parcels would be affected at the 416 elevation was made. For identification purposes each parcel was assigned a D.W.R. reference number, there being 782 in all. This tabulation shows the D.W.R. reference number, property description, owner, area, assessed valuation of land and improvements, and for each of the four proposed water surface elevations the flooded area.

A tabulation was made of sales since 1941, based upon transcripts from the County Recorder. This tabulation shows the general location of the sales, property owners, and revenue stamps on the deed. By selecting parcels within the proposed reservoir and allowing for a reasonable increase in market value between 1944 and 1946, an over-all mean ratio of market value to 1946 assessed valuation was fixed at 5 for the farm property (that is lands easterly of the westerly land of Rancho San Bernardo). In the Campo Del Dios Subdivision, sales for 1946 and 1947 were tabulated. The ratio of market value to 1946 assessed valuation was 4.6 for lots only and for lots with improvements the ratio was 5.6. It was decided to use a mean ratio of 6 for this subdivision property.

An inspection of the reservoir site and property to be evaluated was made by G. F. Mellin and B. A. Etcheverry accompanied by H. M. Crooker and the writer. During the course of the inspection, conversations were held with Crowell D. Eddy, County Assessor,

Mr. Robert Henrich and Mr. Charles Mendenhall of the Assessor's office, and Mr. Arthur Wade, Manager of the Del Dios Water Company. As a result of their inspection, the following decisions were made by Messrs. Etcheverry and Mellin:

1. That the valuations used by the County Assessor were sound and consistent and therefore could be used as a basis for right of way costs by applying a factor equal to the ratio of market value to County Assessor's valuations.

2. That for the farm property the factor of market value to 1946 assessed valuation should be 5.

3. That for subdivision property in Campo Del Dios, the factor of market value to 1946 assessed valuation should be 6.

4. The limits of the property to be purchased and the estimated damages to property severed. (Shown on maps)

5. That it would be necessary to purchase the entire Del Dios Subdivision at all elevations considered. This was based upon the fact that the water supply of the mutual water company would be flooded at elevation 368, that the main water line to the entire subdivision would also be flooded, and that nearly half of the property would be flooded at elevation 368, which in itself would greatly depreciate the remainder.

6. That wherever new improvements had been constructed after the 1946 tax roll was made up, the 1947 assessed valuations when available would apply.

7. That an estimate should be made of the cost of relocating power and telephone circuits.

Improvements constructed subsequent to March 1946 were valued by using the 1947 assessment and the same factors as applied to 1946 assessment. This applied to four parcels in the San Pasqual Valley and 12 lots in the Del Dios Subdivision. There were four new houses in Del Dios which had not been assessed for 1947. Values were estimated for these.

Both the San Diego Gas and Electric and Pacific Telephone and Telegraph Company have circuits in or through the reservoir site. Mr. G. E. Jenner, of the San Diego Gas and Electric, was contacted for information regarding cost of relocating two feeder circuits which would be affected. Mr. John A. Redlon, of the telephone company, was contacted regarding the toll circuit across Lake Hodges. Damages to each utility were estimated by each company at approximately $40,000 for the maximum water surface elevation.

SUMMARY

HODGES RESERVOIR RIGHT OF WAY COSTS

San Dieguito Investigation

	Acres Flooded less City-owned	Acres Purchased (Non-City)	Cost of Land	Cost of Improvement	Damage	Total Cost
ELEVATION 368						
San Pasqual Valley and Bernardo	669	1,142	$159,900	$45,020	$33,870	$238,790
Del Dios	48	80	221,520	502,020	0	723,540
San Diego Gas and Electric Company	0	0	0	0	33,000	33,000
Pacific Telephone and Telegraph Company	0	0	0	0	30,000	30,000
TOTALS	717	1,222	$381,420	$547,040	$96,870	$1,025,330
ELEVATION 382						
San Pasqual Valley and Bernardo	1,268	2,342	$254,710	$71,170	$36,700	$462,580
Cloverdale Ranch			89,000	11,000	0	100,000
Del Dios	48	80	221,520	502,020	0	723,540
San Pasqual School		0	0	0	0	0
San Diego Gas and Electric Company		0	0	0	34,000	34,000
Pacific Telephone and Telegraph Company		0	0	0	32,000	32,000
TOTALS	1,316	2,422	$565,230	$584,190	$102,700	$1,352,170
ELEVATION 396						
San Pasqual Valley and Bernardo	1,955	4,008	$330,080	$239,940	$43,000	$819,020
Cloverdale Ranch			89,000	11,000	0	100,000
Del Dios	48	80	221,520	502,020	0	723,540
San Pasqual School	0	0	0	0	0	0
San Diego Gas and Electric Company	0	0	0	0	36,000	36,000
Pacific Telephone and Telegraph Company	0	0	0	0	36,000	36,000
TOTALS	2,001	4,148	$640,600	$752,960	$115,600	$1,715,160
ELEVATION 416						
San Pasqual Valley and Bernardo	3,168	4,791	$593,720	$272,670	$36,550	$904,940
Cloverdale Ranch			89,000	11,000	0	100,000
Del Dios	48	80	221,520	502,020	0	723,540
San Pasqual School	0	0	0	0	2,000	2,000
San Diego Gas and Electric Company	0	0	0	0	40,000	40,000
Pacific Telephone and Telegraph Company				0	40,000	40,000
TOTALS	3,216	4,871	$904,240	$785,690	$120,550	$1,810,480

B. A. ETCHEVERRY
Consulting Civil Engineer

12 Engineering Building
Berkeley

May 28, 1947

Mr. Edward Hyatt, State Engineer   Subject: Cost of Lands for
401 Public Works Building   Mission Gorge
Sacramento 5, California   Reservoirs

Dear Sir:

        At your request we have estimated the present day market value of the lands
and improvements in the proposed Mission Gorge Reservoirs, including all properties
(excepting the lands already city owned) up to contour 350 for dam sites No. 2 and No. Zero
and to contour 331 for dam site No. 3. We herewith submit a brief statement of the work
done and a summary of our findings.

        It was our understanding that the contours to be considered were 331 and 353.
However, the map of Mission Gorge Reservoir Topography (Scale 400' = 1") prepared by
Fairchild Aerial Surveys, Inc., had on it contours at 10-foot intervals to 350, but not
353, and the slope of much of the land above 350 is so flat that contour 353 could not be
extrapolated with any degree of accuracy. We therefore used contours 331 and 350. If it
is important to extend our appraisal so as to include lands up to contour 353, this can be
easily done by having Fairchild Aerial Surveys, Inc. locate this contour accurately on the
topographic map. As commented upon later in this report, contour 350 seems to include all
of, if not more than the properties which may have to be acquired.

        On the above stated topographic map the property ownership boundaries and the
soil classification lines were transposed.

        For all the properties involved we also had all basic data, including:

        (a) Descriptions and acreages of the properties; and
        (b) County Assessor's data for 1946 valuations.

        The records of the County Assessor's valuation give detailed dependable infor-
mation on all of the improvements at the time of the valuation, and the valuations of
lands and improvements are complete and consistent.

        As an indication of market value of properties, Mr. D. B. Willets of the Divi-
sion of Water Resources had compiled for us the data and information on sales of properties
within and adjacent to the proposed reservoir lands. These data were tabulated together
with the corresponding 1946 County Assessor's valuations and we made an analysis of the re-
lation of sales values to the 1946 Assessor's valuations, with proper allowances for the
increase in market values from the dates of the sales to the present. This analysis showed
that a very good estimate of present day market values of the properties involved would be
obtained by using the following factors or ratios of market value to 1946 County Asses-
sor's valuations: (1) a factor of 4 for all unimproved farm properties (2) a factor of 4
for the land and 6 for the improvements for all the improved properties. These are gener-
ally small tracts with residential improvements; (3) a factor of 4 for the land and 5 for
the improvements for the Scripps and Good Ranches. On these ranches the improvements are
mostly in farm buildings.

        Our field survey showed there were 18 buildings either new or under construction
below elevation 350, that had not yet been valued by the County Assessor. We estimated the
market value of these buildings and found their total market value to be $60,000 - simi-
larly we found four new buildings below elevation 331, with a total market value of $9200.

        We found that the County Poor Farm (known as Edgemore) was so situated that only
a flowage easement over it should be acquired, and we made a separate appraisal of this
easement. This farm contains 472 acres, of which 385 acres are below elevation 350. The
lowest land is at elevation 330. About 2/3 of the land is above elevation 340 which eleva-
tion is subject to an average frequency of flooding of approximately once in 55 years. The
residential improvements are above elevation 348.   These would be about 3 feet above ele-
vation 345 which has an average frequency of flooding of about once in 250 years. Because
of these conditions we appraised the value of the flowage easement at 30 percent of the fee
value of the 385 acres of land below elevation 350.

For all of the other properties and for both contours, 331 and 350, we estimated the fee values. Where these contours cut properties so as to damage the remainder of the property above the contours, we have estimated the damage.

Our findings on the total present day market value of all the lands and improvements, including the value of the flowage easement on the County Poor Farm, are summarized in the following tabulation:

Dam sites	No. Zero and No. 2	No. 3
High water elevation	350	331
Acres to be flooded (excluding City owned)	1915	1163
Acres to be purchased (excluding City owned)	2035	1202
Estimated cost of: Lands	$212,930	$ 58,690
Improvements	463,740	127,620
Damages or/and flowage easement	40,140	24,890
TOTAL	$716,810	$211,200

The above estimated total costs do not include the estimated cost of relocation of roads and pipe line. In Bulletin No. 48 of the Division of Water Resources (San Diego County Investigation) their estimated costs for Dam Site #2 and also for #3 are as follows:

Relocation of Roads 5 miles at $20,000	$100,000
" " Pipe line 5.2 miles at 45,000	234,000
TOTAL	334,000

Comments - In accordance with your request we have estimated the cost of reservoir lands with improvement for lands below contour 331 and contour 350. May we suggest that considerable savings in cost would be obtained by limiting the purchase in fee to lands which have a reasonable average frequency of flooding and obtaining flowage easements on the remainder. The merit of this suggestion is indicated by the following data from Bulletin 48, pertaining to Mission Gorge No. 2 reservoir when used for conservation:

Crest flows at Mission Gorge #2
spillway

Average frequency of crest flow	once in 25 yrs.	once in 50 yrs.	once in 100 yrs.	once in 250 yrs.
Crest flow in sec. ft.	0	16,200	33,100	50,100
*Corresponding H.W. level in reservoir	336	339.4	342	344.5

*The corresponding high water levels are computed on the basis of an overpour crest 510 ft. long at elevation 336.

The foregoing tabulated results are for crest flows. The corresponding mean daily high water level would be somewhat lower. For farming lands a frequency of flooding of once in 50 years or even once in 25 years would produce little if any damage. However, the possibility of flooding would destroy the use of the lands for residential purposes and would be a factor in estimating the value of flowage easement. We believe - (1) that for residential lands it may be desirable to acquire lands in fee below elevation 345 instead of 350. A material part of the existing residential improvements is between these contours - (2) that for farming lands it may be desirable to acquire lands in fee below elevation 336 and in flowage easement above that elevation up to 345.

We attach as part of this Report the accompanying statement of Procedure followed in this Appraisal.

The collection and compilation of the data used by us was made by Mr. D. B. Willets who accompanied us on our trip to San Diego, and worked with us. We appreciate his competent help.

<div align="right">
Respectfully submitted,

/s/ <u>B. A. Etcheverry</u>
     B. A. Etcheverry

/s/ <u>G. F. Mellin</u>
     G. F. Mellin
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PROCEDURE FOLLOWED IN ESTIMATING RIGHT OF WAY COSTS
FOR MISSION GORGE RESERVOIRS

Right of way costs were estimated for three reservoir sites and two water surface elevations as shown below:

Site	Maximum W.S.Elev. Feet	Reservoir Capacity Ac.Ft.
0	350	23,700
2	350	29,200
3	331	29,200

Basic data on property owners, property descriptions, assessed valuations, and recent sales were secured in the San Diego County Assessor's office.

Topography of the reservoir area is shown on map entitled Mission Gorge Reservoir Topography, Scale 400' = 1", dated July 1946, prepared by Fairchild Aerial Surveys, Inc. The various dam sites and maximum water surface contours 331 and 350 were plotted as well as property owners in and adjacent to the proposed reservoir. As an additional aid in making the appraisal, soil classifications were indicated on the maps.

For the Mission Zero and Mission No. 2 sites, a tabulation of all the property owners whose parcels would be affected at the 350 elevation was made. Each parcel was assigned a reference number and the tabulation shows the property description, owner, area, assessed valuation of land and improvements for 1946 and for 1947 where available, and the area flooded. The flooded area for each parcel was determined by planimeter on the maps mentioned in the preceding paragraph. For the Mission Gorge Dam Site No. 3, the maximum water surface for desired reservoir capacity of 29,200 acre feet is 331. Accordingly, a tabulation of all property owners whose land would be affected at the 331 elevation was made. This tabulation was similar to the one made for the other site and shows similar information.

For the tax year 1946-47, a tabulation of sales within and adjacent to the proposed reservoir was prepared. The information in this tabulation, comprising location of the sale, property owners, and revenue stamps on the deed, was based upon transcripts from the County Recorder. From these sales certain transactions were eliminated since there was uncertainty as to the status of improvements on the property at the time the sale was made. The summary of the remaining sales shows that for land only, the ratio of market value to assessed valuation is 4.0, and for land with improvements (where improvements were the controlling element) the mean ratio of market value to assessed valuation is 5.9.

In the Mission Valley area there has been considerable activity both as respects the sale of property and construction of improvements during the past few years. A field survey of the proposed reservoir area indicates that in the area below elevation 350 there are 18 buildings either new or under construction which had not been assessed or reassessed by the County Assessor as of the fifth of May 1947. Based on size and type of construction, the total estimated market value of these 18 buildings is $60,000. For the Mission No. 3 Site with reservoir elevations to 331, there are only four new buildings, not assessed, having an estimated market value of $9,200.

All public utilities within the area, except the pipe line are located on road rights of way and it is our understanding that costs of their relocation are not involved in this appraisal. Costs of relocating pipe line and highway are not estimated.

An inspection of the reservoir site and property to be appraised was made by B. A. Etcheverry, G. F. Mellin and D. B. Willets on May 15 and 16. As a result of this inspection and the study of the data compiled from the records of the County Assessor, the following decisions as to appraisal of this property were made:

1. That the valuations used by the County Assessor were sound and consistent and therefore could be used as a basis for estimating right of way costs by applying a factor equal to the ratio of market value to County Assessor's valuation.

2. That for the unimproved property, the factor of market value to 1947 assessed valuation should be 4.

3. That for the improved property the factor of market value to 1947 assessed valuation should be 4 for the land and 6 for the improvements except as noted in succeeding paragraphs.

4. That the factor of market value to assessed valuation for improvements on the Scripps and Good ranches should be 5 rather than 6, since most of these improvements were farm buildings rather than residences.

5. The limits of property to be purchased and estimated damages to property severed were indicated on the maps.

A separate appraisal was made of the County Poor Farm known as Edgemore. Although 385 acres out of 472 acres of the farm would be flooded at elevation 350, the larger part of these 385 acres would be subject to very infrequent shallow flooding of short duration. It was also noted that all of the buildings used as residences or recreation rooms for the men were above elevation 350. The only improvements below elevation 350 are a few barns which would not be seriously damaged by high water. In view of these considerations the only right of way cost which was considered applicable to the County Farm was the purchase of a flowage easement over the 385 acres flooded at elevation 350. It was decided this flowage easement would be valued at 30 per cent of the fee value of the land.

Following is a summary showing for each reservoir site and each elevation of maximum water surface the areas flooded, the area to be purchased, the cost of land, the cost of improvements, the estimated damages and total estimated right of way cost. The item of damage includes the cost of flowage easements wherever applicable.

Summary

Item	Sites Zero and 2 H. W. Elev. 350	Site 3 H. W. Elev. 331
Area to be flooded excluding city owned land	1915 acres	1163 acres
Area to be purchased excluding city owned land	2035 "	1202 "
Cost of land	$212,930	$ 58,690
Cost of improvements	463,740	127,620
Damages and/or Flowage Easements	40,140	24,890
Total R/W Cost	$716,810	$211,200

APPENDIX D

PRELIMINARY PROGRESS REPORT
ON CONSUMPTIVE USE OF WATER INVESTIGATIONS
IN SAN PASQUAL VALLEY, CALIFORNIA

By
Harry F. Blaney, Senior Irrigation Engineer
and
Dean C. Muckel, Associate Irrigation Engineer

Division of Irrigation
Soil Conservation Service
United States Department of Agriculture
September 14, 1945

Preliminary Progress Report on

CONSUMPTIVE USE OF WATER INVESTIGATIONS IN

SAN PASQUAL VALLEY, CALIFORNIA[1]

Introduction

At a meeting on June 21, 1945 between W. W. McLaughlin, Chief of the Division of Irrigation, Soil Conservation Service, U. S. Department of Agriculture, and Edward Hyatt, State Engineer of California, it was suggested that a study of consumptive use of water in San Pasqual Valley, located in the San Dieguito River watershed (San Diego County), be undertaken under the regular cooperative agreement between the government and the state.

On July 6, 1945, at the request of the State Engineer, a conference was held to consider the proposal. Those attending the conference included Edward Hyatt, State Engineer, A. D. Edmonston, Deputy State Engineer, and P. H. Van Etten, Senior Hydraulic Engineer, of the California State Division of Water Resources; and A. T. Mitchelson and Harry F. Blaney of the Division of Irrigation. It was agreed that Harry F. Blaney and Dean Muckel would undertake to make a preliminary estimate of unit values of consumptive use of water by various types of vegetation, prior to October 1, 1945, based on previous field studies in the San Luis Rey Valley. Also that the Division of Irrigation staff would outline a procedure for determining the acreages of water-using areas by the field engineers of the State Division of Water Resources.

This procedure was outlined at a field meeting in San Pasqual Valley on August 7 and by a memorandum to W. W. McLaughlin, dated August 11. On August 7 and 8 an inspection of San Pasqual Valley was made with A. D. Edmonston, P. H. Van Etten and H. M. Crooker of the State Division of Water Resources, and Fred Pyle, Hydraulic Engineer of the City of San Diego. H. M. Crooker is conducting the field work for the State water-supply study, under the supervision of P. H. Van Etten.

The purpose of this report is to set up tentative unit consumptive use values for making a preliminary estimate of valley consumptive use by the integration method. Briefly stated, the integration method is the summation of the products of consumptive use for each crop times its area, plus the consumptive use of native vegetation times its area, plus water surface evaporation times water surface area, plus evaporation from bare land times its area. This method has been used by the Division of Irrigation in San Luis Rey Valley and other investigations. Before the integration method can be successfully used, it is necessary to know unit evapo-transpiration or consumptive use of water and the areas of various classes of agricultural crops, native vegetation, bare land, and water surfaces. When the acreages of various land classifications in San Pasqual Valley have been determined by the State Division of Water Resources, the valley consumptive use can be computed.

A more refined estimate of unit consumptive use values could be made from evaporation and temperature records if they were made available by establishing a station in San Pasqual Valley in the near future. Escondido has a long record of temperatures and precipitation. Relatively short evaporation and temperature records in San Pasqual Valley could be used to correlate the climatic conditions in the valley with those of Escondido and San Luis Rey. Also a field study of irrigation practice in the San Pasqual Valley would be helpful in making a better estimate of unit use values for irrigated crops.

Owing to the limited time allotted it has not been possible to do any field work or to collect existing ground-water records in the Valley. Also the results of a field study on evaporation and transpiration losses in San Pasqual Valley, made by F. E. Green in 1923-24 for J. B. Lippincott, should be analyzed before a final report is submitted. For this purpose, all available records on temperature, precipitation and depth to ground water in the Valley are needed. Consequently the unit consumptive use values, as reported herein, are necessarily tentative.

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[1] Prepared by Harry F. Blaney, Senior Irrigation Engineer, and Dean C. Muckel, Associate Irrigation Engineer, Division of Irrigation, Soil Conservation Service, U. S. Dept. of Agriculture, under the direction of W. W. McLaughlin, Chief of Division of Irrigation. September 14, 1945.

Unit Consumptive Use of Water [1]

　During the 5-year period, 1939 to 1944, the Division of Irrigation, Soil Conservation Service, made studies in San Luis Rey River Valley, San Diego County, and has available unit consumptive use values for this area. [2] The San Luis Rey Valley units were reported for the Mission Basin (Coastal conditions); Bonsall Basin (intermediate conditions); and Pala-Rincon (inland conditions). Evaporation, rainfall, temperature and other climatological records were obtained together with tank studies of the consumptive use rate of native vegetation supported by a high ground-water table. Climatic conditions in Bonsall Basin and San Pasqual Valley are much the same and it is believed that the unit use as established for Bonsall Basin can be transferred to San Pasqual Valley with only slight adjustment.

　In order to apply the unit use values there must be a clear understanding of the land classifications as used in the field mapping. Inspection of the San Pasqual Valley in August 1945 revealed that lands here would fall under one of the classifications shown in table 1.

Table 1 - Classification of water-using areas in San Pasqual Valley, Calif.

Classification	Description
IRRIGATED 1. Alfalfa, pastures 2. Field crops - grain, truck 3. Orchard	
DRY FARMED 4. All crops	These crops receive water from precipitation only.
NATIVE VEGETATION Valley floor	
5. Grass, weeds, pasture	This vegetation gets some or most of its water from a high ground-water table (less than 10-12 feet below the ground surface).
6. Trees, brush and grass (dense growth)	This vegetation gets ample water from a water table for maximum growth the year round. Examples are the fringes along a live stream and in the narrows of San Pasqual Valley where the water table is maintained within a few feet of the ground surface.
7. Trees, brush and grass (medium growth)	This vegetation is less dense than that of classification No. 6 because of a slightly lower water table, poorer soils or has not yet fully recovered from a previous flood. It consists of somewhat scattered trees, intermingled with brush and grasses. Some of the vegetation draws water from the ground water supplies.
8. Trees, brush and grass (sparse growth)	This vegetation survives mainly on direct rainfall although there may be a few scattered trees with deep roots reaching the water table.
9. Swamp, tules, reeds	This land will have a wet or moist ground surface the year round. The water table is too high for the growth of large trees or agricultural crops.
Hillside lands	
10. Grass and brush	This vegetation gets all of its water supply from direct rainfall. It does not have access to ground water.
MISCELLANEOUS	
11. Water surface	Streams and ponds having water the year round. That portion of the stream channel which consists of wet sand the year round may be placed in this classification.
12. Waste land - bare	This is land devoid of any vegetation. The ground water table is a sufficient depth so that there is no loss by evaporation. The consumptive use for this land consists of evaporation after rains.
13. Farm lots	Farm houses, yards, gardens.
14. Roads - surfaced	These lands have water loss only by evaporation after rains. The total area is very small.

[1] Revision of preliminary report prepared by Dean Muckel on August 30, 1945.

[2] Three annual progress reports have been made covering the work in San Luis Rey Valley. The method of mapping and arriving at the various unit consumptive use values is described. A final report is now being prepared.

The unit consumptive use values as determined for a normal year in Bonsall Basin, San Luis Rey Valley, are given in table 2. In order to transfer the San Luis Rey unit consumptive use values to San Pasqual Valley search was made for climatological data. Temperature and rainfall records are available in U. S. Weather Bureau publications for Escondido for many years. Escondido is not in San Pasqual Valley proper but it lies within a few miles of the valley and climatic conditions should be the same. Blaney and Morin [1]/developed an empirical formula by which evaporation and consumptive use can be correlated with temperature, percent of daylight hours and humidity. Percent of daylight hours varies with latitude and the month. It has been worked out by the U. S. Weather Bureau. Because there are no humidity records available in or near San Pasqual Valley, a correlation was tried using only temperature and percent of daylight hours but otherwise following about the scheme of Blaney and Morin. On figure 1 the accumulated total of observed consumptive use in a tank at Bonsall Basin (San Luis Rey Valley) is plotted against the accumulated total of temperature times the percent of daylight hours. The tank contained native vegetation growing in a natural environment with a high water table. The vegetation and growing conditions were comparable to the vegetation classed as "Trees, brush, dense growth". Monthly records of the actual use by the vegetation were obtained for the summer months, April through September, and for the six-month winter period, October through March, when rainfall interfered with soil moisture conditions and made it impossible to measure the use by individual months. The figures used in developing the curve were for a normal period insofar as temperature and evaporation were concerned.

Table 2 - Unit consumptive use values for normal year, as determined for Bonsall Basin in San Luis Rey River Valley, San Diego County, California

Classification	Annual consumptive use*
IRRIGATED	Feet
Citrus	2.2
Deciduous trees	2.6
Avocados	2.2
Alfalfa	3.3
Grain, hay	1.5
Vegetables	1.3
Miscellaneous	1.5
DRY FARMED	
Valley floor	1.5
Hillside lands	1.3
NATIVE VEGETATION	
Valley floor	
Pasture, saltgrass	2.6
Swamp, tules, reeds	4.8
Brush, trees, grass	
Dense growth	4.6
Medium growth	2.4
Sparse growth	1.5
Hillside lands	
Brush and grass	1.3
MISCELLANEOUS	
Water surface	3.9
Wasteland-bare	0.7
Towns, farmlots	2.0
Roads, surfaced	0.5

* Revision of table 24 of Third Progress Report of Cooperative Studies on Water Utilization in San Luis Rey Valley, California.

It will be noted that there is very nearly a straight line relationship between the consumptive use and the product of temperature and percent of daylight hours if the year is broken into two six-month periods - winter and summer.

1/ Blaney, Harry F., and Morin, Karl V. - Evaporation and Consumptive Use of Water Empirical Formulas. Amer. Geo. Union Trans. 1942, Part 1-B.

FIG. I
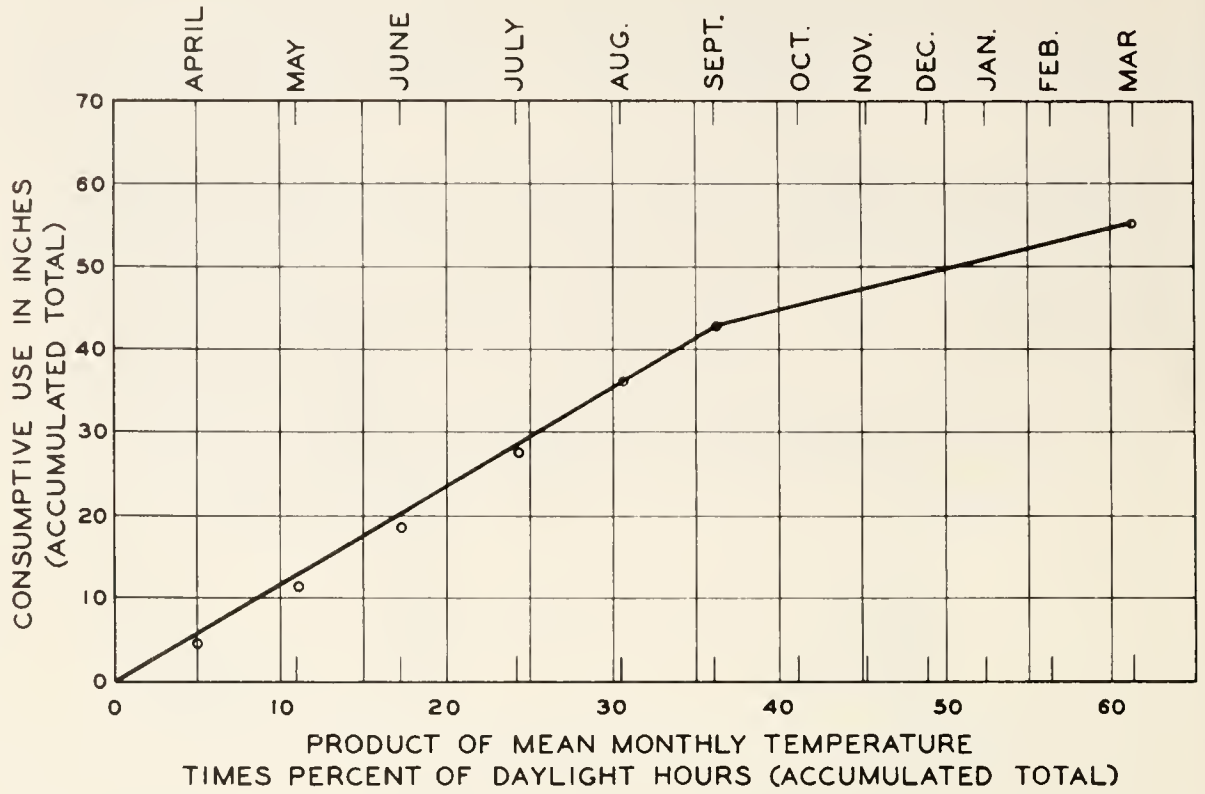
RELATION BETWEEN OBSERVED CONSUMPTIVE USE
BY
NATIVE VEGETATION AND THE PRODUCT
OF
MEAN TEMPERATURE AND PERCENT
OF
DAYLIGHT HOURS
(NEAR BONSALL, CALIF.)

In table 3 the consumptive use has been computed for Escondido temperature conditions based on the ratio found in Bonsall Basin. The normal annual consumptive use by dense vegetation at Escondido amounts to 56 inches (4.7 feet) as compared with 55 inches (4.6 feet) in Bonsall Basin or on a percentage basis, 102 percent of the use in Bonsall Basin. This ratio is assumed to hold for all types of crops, including irrigated, dry farmed and native vegetation of different densities.1/ The product of temperature times percent of daylight hours is slightly more at Escondido during the summer six months and slightly less during the winter six months than that in Bonsall Basin.

The consumptive use of 56 inches for dense vegetation is for a normal year. To arrive at the uses for each individual year the temperatures at Escondido were tabulated for the period 1906 to 1944 from U. S. Weather Bureau records. The ratios of use, divided by temperature times percent of daylight hours (Use/t x p) of 1.19 for the summer six-month period and 0.48 for the winter six-month period were then applied to each individual year. These computations are shown on table 4. The annual indices were then computed as a percentage of the long time average. It will be noted that there is very little variation in the annual indices. The maximum is 104 percent and the minimum is 96 percent. Considering the accuracy by which consumptive use can be measured and by which vegetated areas can be mapped and classified the variation in annual use might be disregarded and the long time average unit uses applied to each individual year for which there is a crop survey.

Table 3 - Observed and computed use of water by native vegetation at Bonsall Basin and Escondido, California

Period	Bonsall Basin				Escondido	
	t x p*	Observed consumptive use	Use / t x p*	t x p*	Computed consumptive use	
		inches			inches	
April through September	36.27	43	1.19	37.2	44.3	
October through March	25.11	12	.48	24.5	11.8	
Year		55			56.1	

* Temperature (t); percent of daylight hours (p).

Attempts were made to incorporate the growing period as determined by U. S. Weather Bureau data on dates on which the last killing frost in the spring and the first killing frost in the fall occurred, but no correlation could be established. Rainfall varies considerably from year to year but for vegetation with a high water table this will have little if any effect owing to the fact that the vegetation gets ample water for maximum growth from the ground water sources. Irrigated crops, particularly citrus orchards, are given water as needed and the rainfall may have little effect on its total consumptive use. Possibly the greatest effect that variation in annual rainfall has on valley consumptive use is in the distance to the water table. In wet years the water table may be higher than in others resulting in a more dense growth of vegetation. This should show up in the crop survey. The consumptive use of hillside vegetation varies to some extent with the seasonal total and distribution of rainfall. In years of subnormal precipitation the vegetation may suffer from lack of water and the consumptive use is lower than average. In wet years the vegetation may become more luxuriant as a result of more available water for a longer period. The consumptive use of vegetation which gets its entire water supply from rainfall will not, however, vary as much as does the rainfall. In San Luis Rey watershed it was estimated that the hillside vegetation used 1.3 feet per year and any rainfall exceeding this amount either ran off as surface flow or penetrated below the root zone. The average annual rainfall at Escondido is 16.60 inches which is undoubtedly exceeded in the higher elevations of the San Pasqual watershed.

Distribution of rainfall will affect the consumptive use by vegetation growing without irrigation or not underlain by a high water table. Usually this vegetation receives water by direct rainfall starting in November or December and ending in April or May. The summer periods are always dry and the vegetation either dies or becomes dormant after the moisture from the last rain is extracted from the soil. A cooperative

1/ Although this relation may not hold exactly for irrigated areas, the use by these crops is small compared to the other classifications. More accurate results can be obtained by a field study of agricultural crops, if necessary.

Table 4 - Temperature data and computed index of consumptive use at Escondido for period 1906 to 1944
as based on native vegetation study in Bonsall Basin, San Luis Rey Valley, Calif.

(Table is based on San Luis Rey unit consumptive use for dense vegetation in Bonsall Basin as 4.6 feet)

Year	Mean Monthly temperatures at Escondido													April through September			October through March			Year	Percent of average	Dates of killing frost at Escondido		
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual	Average temperature (t)	t x p 1/	U_s 2/	Average temperature(t)	t x p 1/	O_w 3/	U 4/		Last in spring	First in autumn	No. of days between dates
1906	49.6	57.0	56.8	53.8	63.4	69.4	76.4	72.4	69.2	64.2	53.0	50.9	61.3	67.4	37.5	44.6	55.3	24.6	11.8	56.4	101	Apr 2	Oct 20	201
1907	48.0	56.2	53.2	59.9	61.4	65.8	73.2	70.1	63.6	60.8	56.6	52.1	60.1	65.7	36.5	43.5	54.5	24.2	11.6	55.1	98	Apr 3	Nov 16	227
1908	51.4	50.4	55.0	58.9	59.4	64.7	72.6	72.4	69.0	58.0	54.0	48.0	59.5	66.2	36.8	43.8	52.8	23.5	11.3	55.1	98	May 16	Oct 23	160
1909	51.0	51.5	53.1	59.4	62.2	67.8	71.2	74.7	70.0	64.4	57.8	52.5	61.3	67.2	37.6	44.7	55.1	24.5	11.8	56.5	101	Mar 13	Oct 30	231
1910	50.9	52.1	58.6	62.2	65.9	67.4	74.0	72.7	72.6	63.6	56.6	53.0	62.5	69.1	38.4	45.7	55.8	24.8	11.9	57.6	103	Feb 18	Oct 12	236
1911	53.8	49.7	57.8	58.1	61.8	66.4	72.4	72.8	68.2	62.9	58.8	48.0	60.9	66.6	37.0	44.0	55.2	24.5	11.8	55.8	99	Apr 15	Nov 25	224
1912	54.6	52.4	53.2	56.2	63.4	68.6	75.3	71.5	68.2	62.0	58.0	48.5	61.0	67.2	37.3	44.4	54.8	24.3	11.7	56.1	100	Feb 26	Dec 6	284
1913	46.9	51.8	53.6	58.9	61.6	66.8	72.6	74.3	73.0	62.8	55.4	49.8	60.6	67.9	37.7	44.9	53.4	23.7	11.4	56.3	100	Mar 27	Dec 3	251
1914	52.0	53.5	59.6	61.0	61.8	68.4	72.8	72.8	69.6	65.0	61.4	47.5	62.1	67.7	37.6	44.7	56.5	25.1	12.0	56.7	101	Feb 8	Dec 15	310
1915	49.0	51.2	57.4	59.8	62.1	69.0	72.4	73.9	67.8	62.4	54.5	50.1	60.8	67.5	37.5	44.6	54.1	24.0	11.5	56.1	100	Jan 20	Nov 11	295
1916	47.7	53.8	58.8	60.3	62.4	68.4	72.4	73.1	69.2	58.0	52.7	46.7	60.2	67.6	37.6	44.7	53.0	23.5	11.3	56.0	100	Feb 2	Oct 30	271
1917	46.5	51.0	52.4	57.7	60.4	70.6	74.0	72.6	69.8	63.4	55.6	51.5	60.5	67.5	37.5	44.6	53.4	23.7	11.4	56.0	100	Apr 1	Nov 15	228
1918	51.2	52.8	55.8	58.5	60.2	71.6	71.4	72.4	72.4	67.6	56.1	51.4	61.8	67.8	37.7	44.9	55.8	24.8	11.9	56.8	101	Feb 17	Nov 8	264
1919	53.4	48.4	52.0	58.2	62.3	68.4	71.2	71.2	68.0	60.3	57.4	55.0	60.5	66.6	37.0	44.0	54.4	24.2	11.6	55.6	99	Mar 15	Nov 28	258
1920	54.3	54.2	53.2	56.5	62.3	66.6	72.2	73.4	68.8	60.2	56.7	52.1	60.9	66.6	37.0	44.0	55.1	24.5	11.8	55.8	99	Mar 28	Dec 21	296
1921	51.7	53.5	56.8	56.6	58.4	66.0	72.6	71.8	68.5	65.2	29.6	56.9	61.5	65.6	36.5	43.4	57.3	25.5	12.2	55.6	99	Apr 17	Nov 18	215
1922	48.9	50.2	51.4	53.9	62.4	68.2	70.7	73.6	72.8	62.0	54.4	54.5	60.2	66.9	37.2	44.3	53.6	23.8	11.4	55.7	99	Apr 11	Nov 4	207
1923	53.8	51.2	55.1	56.9	63.4	63.1	68.7	69.4	68.6	62.0	59.6	52.0	60.3	65.0	36.1	43.0	55.6	24.7	11.9	54.9	98	Mar 16	Dec 12	271
1924	51.4	55.6	51.1	55.4	63.0	67.0	68.8	68.6	68.2	58.4	59.2	51.3	59.8	65.2	36.2	43.1	54.5	24.2	11.6	54.7	98	Apr 17	Oct 12	178
1925	51.4	54.4	55.2	56.2	61.4	66.6	72.6	69.8	65.8	60.2	55.0	54.4	60.2	65.4	36.3	43.2	55.1	24.5	11.8	55.0	98	Mar 13	Nov 6	238
1926	50.0	54.4	57.6	61.4	63.1	68.4	70.6	71.6	65.6	64.1	61.2	49.8	61.5	66.8	37.1	44.1	56.2	25.0	12.0	56.1	100	Jan 28	Dec 15	321
1927	51.6	54.0	52.9	56.5	62.0	65.4	72.2	71.1	66.7	63.7	61.2	51.6	60.7	65.6	36.5	43.4	55.8	24.8	11.9	55.3	99	Mar 20	Dec 8	263
1928	54.6	53.2	56.9	57.2	64.3	66.3	69.9	70.0	69.5	61.8	56.8	53.0	61.1	66.2	36.8	43.8	56.1	24.9	12.0	55.8	99	Apr 5	Nov 30	239
1929	50.2	49.0	54.0	55.7	65.0	67.4	73.1	76.3	70.4	68.0	60.5	59.0	62.4	68.0	37.8	45.0	56.8	25.2	12.1	57.1	102	Mar 25	Nov 21	241
1930	51.7	55.8	56.8	60.6	57.8	65.4	72.6	72.8	66.1	63.6	61.2	54.4	61.6	65.9	36.6	43.6	57.2	25.4	12.2	55.8	99	Jan 9	Nov 19	314
1931	53.9	54.7	58.8	62.6	67.0	69.6	76.0	76.2	70.5	66.2	55.0	50.4	63.4	70.3	39.1	46.5	56.5	25.1	12.0	58.5	104	Mar 9	Nov 22	258
1932	48.4	52.6	56.8	58.9	62.0	66.1	69.2	70.3	68.6	63.3	63.2	50.1	60.8	65.9	36.6	43.6	55.7	24.7	11.9	55.5	99	Feb 4	Dec 15	315
1933	49.0	49.6	54.5	55.6	55.9	63.8	70.1	71.4	64.6	65.0	61.4	53.4	59.5	63.6	35.4	42.1	55.5	24.7	11.9	54.0	96	Mar 26	None	339
1934	54.0	55.8	61.4	61.9	65.3	64.2	72.4	72.1	71.8	66.7	59.0	56.0	63.5	68.1	37.8	45.0	58.8	26.1	12.5	57.5	102	Jan 12	None	353
1935	52.5	55.3	51.4	59.1	60.4	66.4	70.9	74.8	70.0	63.3	55.6	54.8	61.2	66.9	37.2	44.3	55.5	24.7	12.9	57.2	102	Mar 23	Nov 4	226
1936	54.5	53.0	57.8	59.8	64.0	68.0	73.7	73.0	69.3	65.0	60.8	53.8	62.7	68.0	37.8	45.0	57.5	25.5	12.2	57.2	102	Mar 26	Dec 2	251
1937	43.8	51.0	54.0	57.6	62.5	66.6	72.4	72.2	71.4	63.4	57.5	57.0	60.8	67.1	37.3	44.4	54.4	24.2	11.6	56.0	100	Feb 27	Dec 22	298
1938	55.8	53.2	54.2	59.3	61.4	66.0	70.4	73.0	72.5	63.0	56.8	57.0	61.9	67.1	37.3	44.4	56.7	25.2	12.1	56.5	101	Feb 13	Nov 9	269
1939	52.1	47.8	53.2	61.6	62.8	66.0	71.8	73.2	73.3	65.8	61.3	58.0	62.2	58.1	37.8	45.0	56.4	25.1	12.0	57.0	102	Mar 9	Dec 25	291
1940	55.4	54.6	58.3	59.9	68.3	65.3	71.1	71.3	68.4	65.4	56.8	57.3	62.8	67.7	37.6	44.7	58.0	25.8	12.4	57.1	102	Mar 12	Nov 23	256
1941	52.8	55.2	57.3	57.0	65.2	66.0	71.2	71.6	66.4	63.4	60.2	52.8	61.6	66.2	36.8	43.8	57.0	25.3	12.1	55.9	100	None	Nov 22	326
1942	54.2	51.0	54.4	56.6	61.0	65.5	71.3	70.5	66.0	63.0	57.7	54.6	60.0	65.3	36.3	43.2	55.8	24.8	11.9	55.1	98	Mar 26	Dec 6	255
1943	55.0	56.6	57.4	60.2	64.8	65.2	71.0	72.6	71.6	65.0	59.9	53.4	62.7	67.6	37.6	44.7	57.9	25.7	12.3	57.0	102	Feb 10	None	324
1944	53.0	50.4	55.4	56.2	61.8	62.7	67.1	71.2	69.8	64.4	55.5	54.6	60.2	66.0	36.0	42.8	55.6	24.7	11.9	54.7	98	Feb 18	Dec 3	289
Average from U. S. W. B.	50.8	52.5	55.2	58.4	62.5	67.5	72.0	72.1	69.0	62.9	57.3	52.1	61.1	67.0	37.2	44.3	55.1	24.5	11.8	56.1	100	Mar 9	Nov 25	261

1/ p = Percent daylight hours. 2/ U_s - t x p x 1.19 = consumptive use, Apr. 1 to Sept. 30. 3/ U_w = t x p x 0.48 = consumptive use, Oct. 1 to Mar. 31.
4/ U = U_s + U_w = Annual consumptive use.

report by the Division of Irrigation[1] indicates that the average date of the last effective rain in the spring is April 9 and the first effective rain in the fall is November 30 for Escondido. "Effective rain" as used in this publication is a rain of one-half inch or more. Rains of less than one-half inch are assumed to evaporate.

In table 5, unit consumptive use values are shown for a normal year in San Pasqual Valley together with the probable monthly distribution of consumptive use. These values must be considered as preliminary and subject to change as more information becomes available on depth to ground water, evaporation, etc.

Refinement of the preliminary unit uses may be made on the basis of a curve similar to that shown on figure 2. Inspection of the valley during the summer of 1945 indicates that a large portion of the consumptive use was a result of native vegetation supported by a high ground-water table. The curve on figure 2 was developed for San Luis Rey Valley after establishing four points by the use of tank data, diurnal fluctuations of the water table and depth of rainfall penetration. Because there is no distinct dividing line between the classifications of dense, medium and sparse growths the portions of the curve assigned to these classifications are shown as overlapping. Many observation wells would be required before such a curve could be constructed for San Pasqual Valley.

The rate of evaporation from free water surfaces is often used as an indication of consumptive use rate. Its value lies chiefly in providing a means of transferring data from one locality to another. There has been much work done in southern California on transpiration and consumptive use by irrigated crops and native vegetation and in most cases evaporation records were kept during the course of investigation. Because the evaporation rate differs in different type pans it is advisable to use a more or less standard type. Most of the available evaporation records are for a U. S. Weather Bureau type pan 4 feet in diameter and 10 inches deep.

Table 5 - Preliminary estimate of unit consumptive use values for a normal year together with the monthly distribution for San Pasqual Valley, California

Classification	Annual consumptive use
IRRIGATED	Feet
Alfalfa	3.4
Field crops	1.5
Orchard	2.4
DRY FARMED	
All crops	1.3
NATIVE VEGETATION	
Valley floor	
Grass, weeds, pasture	2.7
Swamp, tules, reeds	4.9
Brush, trees, grasses	
Dense growth	4.7
Medium growth	2.4
Sparse growth	1.5
Hillside lands	
Brush and grass	1.3
MISCELLANEOUS	
Water surface	4.0
Farm lots	2.0
Wasteland-bare	0.7
Roads-surfaced	0.5

Monthly distribution of average annual valley consumptive use in percent												
Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
3	3	4	9	12	13	16	15	13	6	3	3	100

[1] Beckett, S. H., Blaney, Harry F., and Taylor, C. A., Bulletin No. 489, Irrigation Water Requirement Studies of Citrus and Avocado Trees in San Diego County, California-1926 and 1927. Univ. of Calif. Agri. Expt. Sta. 1930.

FIG. 2
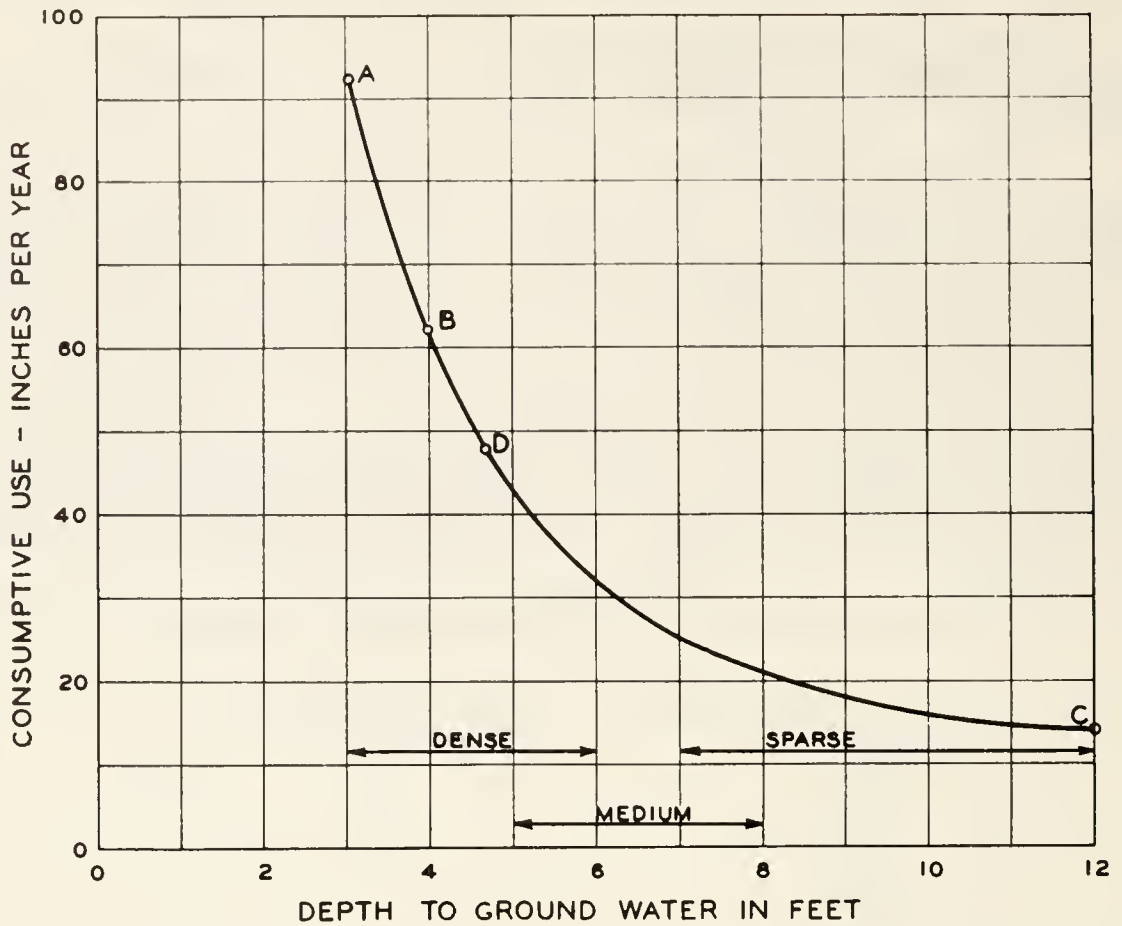
CURVE DEVELOPED FOR SAN LUIS REY VALLEY
SHOWING
RELATIONSHIP BETWEEN CONSUMPTIVE USE
AND
DEPTH OF GROUND WATER FOR NATIVE VEGETATION
(FROM SAN LUIS REY REPORT)

D. MUCKEL

APPENDIX A

Memorandum to Mr. Harry F. Blaney

From: Dean C. Muckel

Subject: San Pasqual Valley, California

        With reference to our telephone conversation of February 8, 1946 regarding the
evaporation rate from bare sands in San Pasqual Valley I have compiled available informa-
tion we have in Pomona. It includes work done by Sleight in Colorado, Young at Santa Ana,
Calif. and F. E. Green for the J. B. Lippincott Engineering Offices in connection with
early investigations in San Pasqual Valley.

        Sleight tested the evaporation rate from 5 different soils with the water table
at different depths and expressed it as the percent of evaporation from a free water sur-
face. He shows that the evaporation rates for different soils vary, as would be expected,
with the capillary rise. Following is a summary for the two types of river-bed material
which he tested and are more or less comparable, I believe, to the river-bed materials in
San Pasqual Valley:

Cherry Creek sands

Water table depth	0	3 inches	6 inches	$10\frac{1}{2}$ inches	24 inches
Soil evaporation in percent of that from free water	77.0	69.0	64.5	57.7	11.3

South Platte graded river-bad material

Water table depth	3 inches	12 inches
Soil evaporation in percent of that from free water	66.0	24.2

        In State Bulletin No. 44 of the South Coastal Basin Investigation Young gives
the evaporation from Hanford fine sandy loam near Santa Ana, Calif. for water table depths
of 2 and 3 feet. In percent of evaporation from a free water surface these amount to ap-
proximately 5 and 9 percent respectively. Capillary rise in this soil will be greater than
in a river-bed material consisting of sands and gravels.

        F. E. Green made tests in San Pasqual Valley, Calif. in 1924 for the J. B.
Lippincott Engineering Offices. Materials used were described as delta sanda formed by
the junction of Santa Maria Creek and Bernardo River in San Paequal Valley and as being
somewhat finer than that in the active channel of the main river. I have only the curve
drawn by Green and it is included on the accompanying diagram. It is notable that for a
shallow water table (the surface soil being saturated) the rate of evaporation from the
soil was greater than from a free water surface. Fortier in some of his early work on
irrigation got similar results.

        The curves on the diagram indicate that the evaporation from river-bed material
is negligible when the water table is 3 feet or more below the ground surface. In finer
soils with greater capillary rise there would undoubtedly be evaporation losses with a
3-foot water table.

        In the units set up in our preliminary report on San Pasqual we gave a figure of
0.7 feet for bare sands. This figure includes losses after rains only and does not in-
clude any losses by capillary rise from the water table. If it is found that the water
table is less than 3 feet I would suggest using Green's curve modified so that when the
water table is at the ground surface the evaporation rate is 100 percent of that from a
free water surface. I have shown this suggested curve on the diagram.

        In most valleys the river channel is alternately dry and wet-dry in the summer
and has flowing water in the winter. This occurred in San Luis Rey Valley and we did not
attempt to set up one definite unit to apply the year round. The consumptive use for
these areas was computed in two parts- one for the winter period based on evaporation from
a free water surface and the other based on the evaporation from bare sands during the
summer. This method requires that an estimate be made of the length of time the channel
or sands have a wet surface.
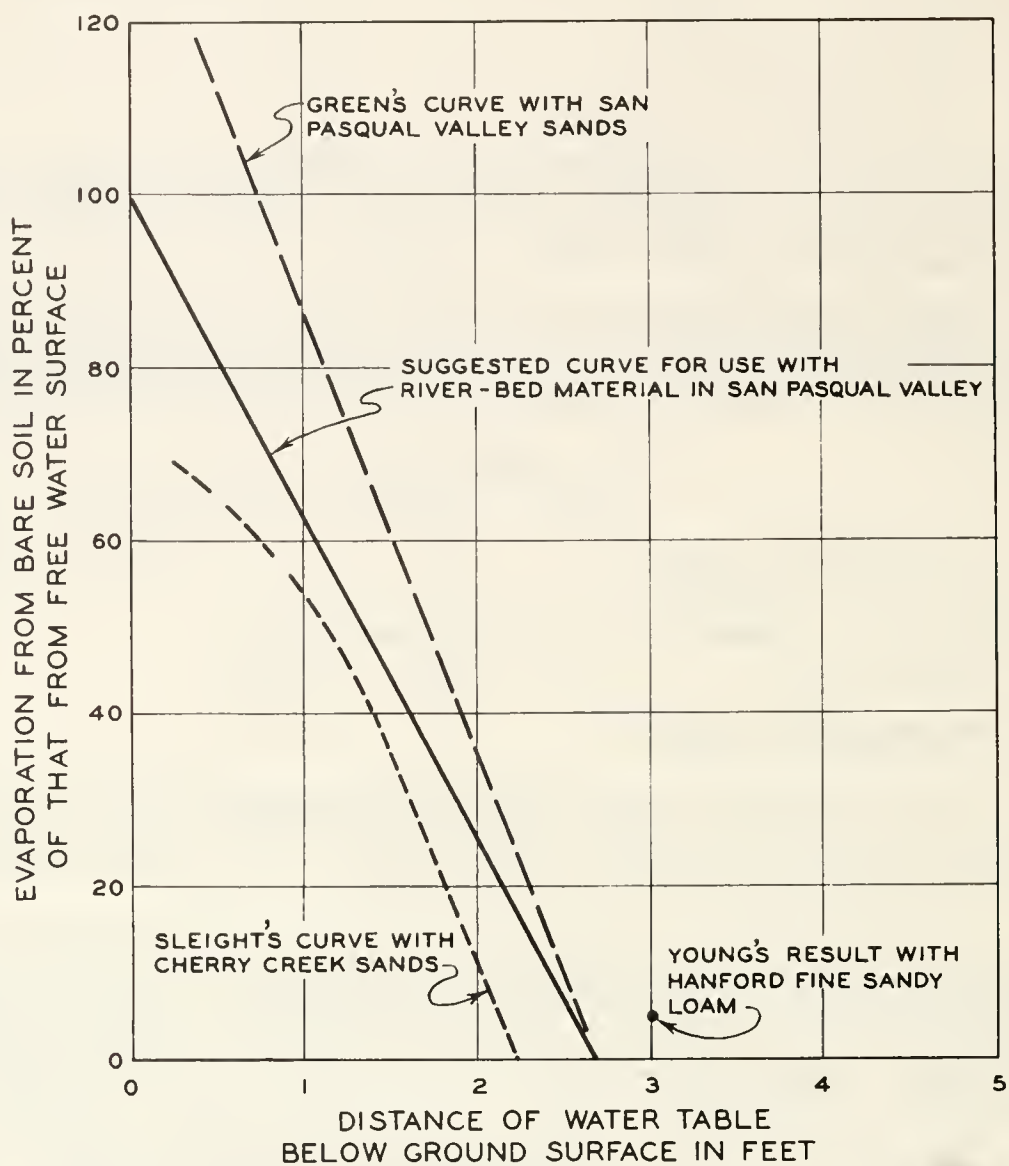
RELATION OF EVAPORATION RATE
FROM SOILS
WITH DEPTH TO WATER TABLE

APPENDIX E

MONTHLY PRECIPITATION RECORDS
AT STATIONS
REPRESENTATIVE OF SAN DIEGUITO BASIN

MONTHLY PRECIPITATION RECORDS AT STATIONS
REPRESENTATIVE OF SAN DIEGUITO BASIN

Precipitation records from the following stations have heretofore been publish-
ed as indicated, and, although utilized in connection with the present investigation, are
not repeated herein:

Index Number Bulletin No. 48	Station	Period of Record to July 1, 1948	Location of Published Record
23	San Felipe	1911-1924*	Bulletin No. 48
28	Matagual	1911-1916	" " "
29	Volcan Mountain	1911-1924	" " "
30	Santa Ysabel-Warner Divide	1913-1916	" " "
32	Damrons	1911-1922	" " "
36	Amago	1912-1944	U. S. Weather Bureau Bulletins
39	Santa Ysabel Ranch	1900-1916	Bulletin No. 48
41	Witch Creek	1909-1916	" " "
43	Rose Glen	1911-1916	" " "
44	Pamo Camp	1914-1923*	" " "
47	Valley Center #1	1872-1903	" " "
48	Valley Center #2	1911-1924*	" " "
50	Rockwood Ranch	1893-1915	" " "
51	Ramona #1 (Verlaque)	1896-1916	" " "
52	Ramona #2 (Sentinel)	1911-1931	" " "
53	Ramona #3	1927-1948	U. S. Weather Bureau Bulletins
55	Escondido #1	1918-1948	" " " "
56	Escondido #2	1894-1935	" " " "
56	Escondido #3	1887-1897	Bulletin No. 48
57	Twin Oaks	1875-1887	" " "
62	Santa Fe Ranch	1912-1915	" " "
63	Poway	1878-1909*	U. S. Weather Bureau Bulletins
69	San Diego	1850-1948	" " " "
101	Julian	1879-1948*	" " " "

* Broken record

Note: "Bulletin No. 48" refers to "Bulletin No. 48, San Diego County Investiga-
       tion", Division of Water Resources, State Department of Public Works, 1935.

In general, the following precipitation records are published herein for the
first time. For many stations these records are in continuation of data for seasons prior
to 1933-34 published in Bulletin No. 48. In a few instances the present records reflect
changes in prior published data, based upon revised or more authoritative information.

Precipitation Station: Henshaw Dam   Elevation: 2,702 feet   Index No. 33
Location: Sec. 10, T. 11 S., R. 2 E.,   Authority: San Diego County Water Company and   Bulletin No. 48
S.B.B.&M.   Vista Irrigation District

Season	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Sea-sonal Total
1933-34	0	0	0	0.22	0.58	3.55	2.81	3.14	0.06	0.18	0	0.32	10.86
1934-35	0.06	0.08	0.38	2.01	1.27	6.22	5.41	4.12	3.92	2.64	0.20	0	26.31
1935-36	0	2.48	0.37	0.21	0.66	0.08	0.48	12.38	4.31	2.08	0.05	0	23.70
1936-37	0.74	0.61	0.02	3.38	0.64	13.64	6.96	14.14	8.42	1.54	0.28	0	50.37
1937-38	0.20	0	0	0	0.14	4.21	3.36	9.79	18.30	1.97	0.81	0	38.78
1938-39	0	0.49	0	0.38	0.10	7.76	4.85	5.09	3.26	1.82	0	0	23.75
1939-40	0	0	7.09	0.40	1.01	1.29	7.33	7.13	0.38	5.45	0.06	0	29.14
1940-41	0	0	0.05	2.29	0.55	12.90	2.25	6.67	10.82	6.80	0.62	0.07	43.02
1941-42	0	1.25	0.13	3.32	3.46	7.39	1.20	5.45	3.39	2.60	0.02	0	28.21
1942-43	0	0.18	0	0.72	0.33	2.81	13.04	4.73	5.52	3.07	0	0.19	30.59
1943-44	0	0	0.56	0.96	0	6.41	2.30	10.01	2.47	2.10	0.30	0.12	25.23
1944-45	0	0	0	0	7.52	1.24	0.80	4.20	9.48	0.57	0	0	23.81
1945-46	0	4.54	0.05	0.12	0.46	10.23	0.72	2.28	5.10	0.96	0.14	0	24.60
1946-47	0.28	0	0.01	2.43	7.73	2.53	1.92	0.94	2.04	1.26	0.83	0	19.97
1947-48	0.05	1.31	0.08	0.29	0.90	4.37	0.10	3.99	4.24	1.75	0.05	0.28	17.41

Additional record published in Bulletin No. 48.

Precipitation Station: Mesa Grande (Angels)   Elevation: 3,450 feet   Index No. 37
Location: Sec. 21, T. 11 S., R. 2 E.,   Authority: C. H. Angel and   Bulletin No. 48
S.P.B.&M.   San Diego County Water Company

Season	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Sea-sonal Total
1911-12	M	M	M	M	M	M	1.30	0.07	15.88	5.30	2.03	M	M
1912-13	0.30	0.91	M	3.33	1.56	0	9.81	8.57	3.65	1.57	0.78	0.67	31.15
1913-14	0.26	1.10	0	5.45	2.89	12.47	7.50	2.70	3.48	0.16	0.88	36.89
1914-15	0	0	0	1.64	1.50	4.98	9.44	11.88	M	4.13	M	M	M
1915-16	0	0.25	0.17	1.80	0	5.44	33.60	2.45	2.86	0.47	0.72	0	47.76
1916-17	0.32	0	0.50	3.98	0.20	4.54	6.82	6.75	1.16	5.06	4.30	0	33.63
1917-18	0.17	0	0	0	1.26	0	3.19	3.46	13.43	0.31	1.61	0.20	23.63
1918-19	0	0.12	0	1.10	3.19	1.60	0.52	5.85	4.72	0.76	0.50	0	18.36
1919-20	0.70	0.40	0.60	2.50	3.00	1.44	1.50	8.50	7.83	1.70	0.63	0	29.00
1920-21	0	0	0	2.51	1.12	2.04	5.26	2.03	5.41	0.92	6.17	0	25.46
1921-22	0	0.95	0	4.45	0.50	20.30	6.95	7.25	4.01	2.14	1.37	0	48.02
1922-23	0	0.56	0.15	1.00	4.57	8.30	0.80	3.50	1.40	3.62	0.12	0.55	24.57
1923-24	0	0	0.10	1.25	1.80	3.11	0.32	0	9.25	4.19	0	0	20.02
1924-25	0	0	0	1.01	3.70	8.70	0.75	2.28	4.04	6.60	0.34	2.65	30.07
1925-26	0	0	0	6.70	1.37	2.50	2.85	7.28	1.55	16.23	0.57	0	40.05
1926-27	0	0	0	0.06	4.07	7.30	1.70	25.72	5.55	1.84	2.27	0.27	48.78
1927-28	0	0	0	4.00	5.98	3.00	3.70	3.19	3.96	0.36	1.37	0.16	25.72
1928-29	0	0	0	.47	3.14	5.92	5.60	5.61	5.63	4.77	0	0.06	31.20
1929-30	0	0.78	0	0.28	0	0	11.80	3.31	6.36	1.72	7.93	0	32.18
1930-31	0	0	0	1.84	5.69	0	3.24	5.79	0.35	6.35	2.15	0.15	25.56
1931-32	0	0.19	0.40	3.25	5.53	11.39	4.27	16.50	1.02	1.83	0.47	1.03	45.88
1932-33	0	0	0.25	2.65	0.50	7.58	8.20	0.42	0.12	5.46	3.20	0.16	28.54
1933-34	0	0	0	0.75	0.65	4.54	2.63	4.67	0.64	0.85	0	1.09	15.82
1934-35	0.15	0	1.24	0.44	2.53	6.95	4.56	5.34	3.81	3.60	0.56	0	29.18
1935-36	0	0.80	0.16	0.52	0.81	1.20	0.56	19.17	4.51	3.10	0.12	0	30.95
1936-37	0.53	0.36	0.50	3.67	1.10	15.55	5.90	15.10	8.62	1.55	1.62	0	54.50
1937-38	0	0	0	0.29	6.56	2.88	14.92	13.87	2.82	1.83	0	43.17
1938-39	0	0	0	0.68	0.27	9.05	5.44	5.47	5.10	3.39	0.27	0	29.67
1939-40	0	0	7.32	1.03	2.14	2.00	8.84	8.34	3.20	5.40	0.05	0	38.32
1940-41	0	0	0	3.17	0.90	13.66	3.62	8.74	13.47	8.56	1.55	0.40	54.07
1941-42	1.00	0	0.25	4.40	4.57	8.47	1.08	4.75	4.00	5.12	0.16	0	33.80
1942-43	0	0	0.45	0	1.58	1.28	3.44	11.72	5.14	7.11	4.50	0	0.70	35.92
1943-44	0	0	0.31	1.47	0.12	8.27	2.80	9.98	4.20	3.12	0.40	1.28	31.95
1944-45	0	0	0	0	8.45	1.35	0.55	5.00	12.90	1.10	0	0.47	29.82
1945-46	0	2.38	0.15	0.39	1.29	14.36	1.94	1.67	0	0	0	0	22.18
1946-47	0	0	0.50	3.36	11.54	4.30	2.10	0.33	3.54	0	0.93	0.14	26.74
1947-48	0	0	0	0	1.55	4.74	0.25	3.58	5.15	3.90	0.60	0	19.77

M - Record missing.

PRECIPITATION (continued)

in Inches

Precipitation Station: Mesa Grande   Elevation: 3,350 feet   Index No. 38
Location: Sec. 3, T. 12 S., R. 2 E.,   Authority: E. H. Davis and Cleason Ambler   Bulletin No. 48
S.B.B.&M.

Season	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Seasonal Total
1936-37	M	M	M	M	0.88	15.88	5.63	21.00	9.00	1.88	0.88	0	M
1937-38	0	0	0	0	0	6.00	4.25	12.63	14.62	2.25	0.50	0	40.25
1938-39	0	0	M	M	M	9.25	5.27	5.78	4.26	1.82	0.22	0	M
1939-40	0	0	7.05	1.02	1.70	2.04	7.79	9.39	0.96	6.88	0	0	36.83
1940-41	0	0	0	3.75	1.30	12.24	3.86	9.61	13.73	10.66	0.55	M	M
1941-42	0	1.75	M	5.35	4.40	8.12	2.60	4.62	4.02	4.89	0	0	M
1942-43	0	M	0	1.00	0.60	2.94	13.35	5.97	6.97	5.85	0	0	M
1943-44	0	0	0.92	1.52	0	9.69	4.05	11.69	5.11	3.46	0.61	1.02	38.07
1944-45	0	0	0	0	9.11	2.05	M	6.49	13.95	1.17	0	0	M
1945-46	0	4.03	0.45	0	1.34	14.62	1.62	2.23	6.30	0.71	1.00	0	32.30
1946-47	0	0	1.39	4.18	9.87	2.95	2.37	1.73	3.75	1.60	0	0	27.84
1947-48	0	0	0	1.00	1.97	5.37	0	5.77	5.37	2.95	0	1.04	23.47

Additional record published in Bulletin No. 48 and by U. S. Weather Bureau.
M - Record missing.

Precipitation Station: Santa Ysabel Store   Elevation: 2,983 feet   Index No. 40
Location: Sec. 21, T. 12 S., R. 3 E.,   Authority: San Diego County Water Company and   Bulletin No. 48
S.B.B.&M.   Santa Ysabel Store

Season	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Seasonal Total
1911-12	M	M	M	M	M	2.05	1.15	0	13.97	4.12	2.00	0.35	M
1912-13	0	0.60	0	3.90	1.35	M	M	5.24	0	0	0	0	M
1913-14	M	0.34	0	0.29	3.31	2.03	8.48	6.25	1.51	3.03	0.32	0.80	M
1914-15	M	M	M	1.59	1.28	4.70	8.63	9.48	2.68	5.43	4.99	0	M
1915-16	0	0.75	0	0	2.22	4.73	29.41	2.19	3.29	0.08	0.54	0	43.21
1916-17	0.20	0.10	0.25	3.03	0	4.31	4.80	4.82	0.81	3.35	1.77	0	23.44
1917-18	0	0	0	0.93	0	2.58	3.61	10.72	0.09	1.28	0.13	0	19.34
1918-19	0	0.86	0	1.11	2.92	3.34	0.20	5.20	4.44	0.94	0.26	0	19.27
1919-20	0.66	0	0.61	2.16	4.41	1.80	1.48	7.43	8.58	1.82	0	0	28.95
1920-21	0.63	0.07	0	2.43	0.34	2.18	4.68	1.86	3.52	0.97	5.52	0	22.20
1921-22	0	0	0	3.31	0.42	20.46	6.12	7.21	3.26	2.27	1.78	0	44.83
1922-23	0.25	0	0	0.81	1.30	7.42	3.90	3.13	2.44	3.22	0	0.37	22.84
1923-24	0	0	0.25	0.95	0.87	3.72	0.77	0	7.66	3.37	0	0	17.59
1924-25	0	0	0	0.75	1.50	6.85	0.66	1.81	3.81	5.17	0.23	2.07	22.85
1925-26	0	0	0	5.89	2.99	1.72	0.93	6.48	12.46	0.37	0.37	0	31.62
1926-27	0	0.25	0	0	2.86	9.64	1.73	21.01	5.20	1.90	2.15	0.16	44.90
1927-28	0.43	0	0	1.33	1.87	6.67	1.10	2.81	2.46	0.38	0.99	0	18.04
1928-29	0	0	0	0.60	1.62	3.88	4.53	3.73	4.92	2.91	0	0	22.19
1929-30	0.27	1.14	1.91	0	0.02	0	11.41	2.87	4.81	2.02	3.83	1.31	29.59
1930-31	0.16	0.65	0	1.05	4.86	0	3.36	5.97	0.32	4.25	1.21	0	21.83
1931-32	0	0.30	0.44	2.31	4.83	8.12	3.35	15.06	0.70	1.86	0.22	0.85	38.04
1932-33	0	0	0.42	3.97	0	6.79	7.64	1.84	0.71	4.44	3.22	0.12	29.15
1933-34	0	0.15	0	0.67	0.41	4.50	1.56	4.40	0.99	0.44	0	0.96	14.08
1934-35	0.12	0	0.44	0.85	2.03	4.17	4.84	5.86	4.40	3.72	0.40	0	26.83
1935-36	0.18	0.81	0.33	0.25	0.59	1.34	0.63	12.94	4.49	2.01	0	0	23.57
1936-37	0.35	0.48	0	2.57	0.84	12.66	4.71	12.45	6.78	1.15	0.65	0	42.64
1937-38	0.27	0	0	0	0.08	3.97	3.46	9.00	13.28	2.28	1.25	0	33.59
1938-39	0	0	0.48	0.61	0.17	9.23	5.84	4.90	2.90	1.37	0.24	0	25.74
1939-40	0	0	5.18	2.14	1.35		5.80	8.26	0.12	5.46	0	0	28.31
1940-41	0	0	0	3.19	1.14	10.01	3.25	5.79	11.24	7.80	0.72	0.49	43.63
1941-42	0	1.93	0.48	3.72	2.32	5.57	2.25	3.51	3.11	3.57	0	0	26.46
1942-43	0	0.64	0	0.85	0.90	2.47	10.10	2.63	5.06	4.62	0.15	0	27.42
1943-44	0	0	0	0.85	0	6.11	7.79	8.86	3.57	1.73	0.65	0	24.56
1944-45	0	0	0	0	7.64	1.74	0.45	4.76	9.79	0	0	0	24.38
1945-46	0.97	3.12	0	0	1.38	8.10	0	3.36	4.52	0.62	0	0	22.07
1946-47	0.95	0	0	4.12	4.51	3.85	1.15	1.15	2.54	1.25	0.35	0	19.87
1947-48	0	0.40	0.31	0.76	0.38	4.22	0	3.89	4.36	1.69	0	1.16	17.17

M - Record missing.

Precipitation Station: Escondido Ditch Head #1 Elevation: 1,755 feet   Index No. 46
Location: Sec. 31, T. 10 S., R. 1 E.,   Authority: Escondido Mutual Water Company   Bulletin No. 48
S.B.B.&M.

Season	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Seasonal Total
1895-96	M	M	M	0.25	M	0.25	3.37	M	5.00	0.25	M	M	M
1896-97	M	M	M	2.75	1.17	2.10	7.80	7.02	4.55	0	0	M	M
1897-98	M	M	M	1.60	0.25	1.25	3.80	0.70	2.42	0.10	M	M	M
1898-99	M	M	M	M	0.26	1.45	3.15	1.80	2.92	0.40	0	0.35	M
1899-00	M	M	M	0.85	2.00	1.70	2.60	M	1.30	2.72	1.92	M	M
1900-01	M	M	M	M	4.97	0	3.70	7.05	1.55	0.25	M	M	M
1901-02	M	M	M	M	M	M	M	M	M	M	M	M	M
1902-03	M	M	M	M	3.19	3.40	2.10	3.60	4.40	5.15	0	M	M
1903-04	M	M	M	M	M	M	M	M	M	M	M	M	M
1904-05	M	M	M	1.25	M	M	M	M	9.55	1.40	4.25	M	M
1905-06	M	M	M	M	5.45	M	2.30	7.51	21.15	M	M	M	M
1906-07	M	M	M	0.10	2.75	4.35	6.25	1.70	6.00	1.15	0.35	M	M
1907-08	M	M	0	5.45	0.90	1.00	6.65	5.35	2.30	1.25	0.75	M	M
1908-09	M	1.00	1.35	0.55	0.80	1.48	10.90	6.75	4.26	0.13	0.17	M	M

M - Record missing.

Precipitation Station: Escondido Ditch Head #2 Elevation: 1,770 feet   Index No. 46A
Location: Sec. 5, T. 11 S., R. 1 E.,   Authority: Escondido Mutual Water   Not listed in Bulletin No. 48
S.B.B.&M.   Company

Season	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Seasonal Total
1909-10	M	0.12	M	M	4.83	8.83	4.05	0.45	5.60	0.95	0.03	M	M
1910-11	0.06	M	M	0.70	1.63	0.33	6.87	6.97	4.48	1.43	0.03	M	M
1911-12	M	0	M	0.88	0.31	2.44	0.60	M	12.80	4.80	2.25	M	M
1912-13	0.25	0.80	M	2.85	2.15	0	2.90	5.75	1.50	1.02	0.55	0.41	M
1913-14	0.25	M	M	M	M	2.10	10.70	10.40	2.70	2.45	0.28	0.40	M
1914-15	M	M	M	M	M	4.96	8.85	9.40	2.52	5.28	3.44	0.05	M
1915-16	M	M	M	M	M	M	M	M	M	M	M	M	M
1916-17	0.17	M	M	M	M	4.35	6.00	3.90	0.80	6.30	2.10	M	M
1917-18	M	0.80	M	M	M	M	4.00	2.75	9.15	M	1.13	1.30	M
1918-19	M	M	M	M	M	3.50	0.60	5.46	4.92	1.15	1.00	M	M
1919-20	0.65	M	M	1.10	2.90	2.38	1.17	8.95	7.71	M	M	M	M
1920-21	M	M	M	M	M	M	M	M	2.90	0.33	5.60	M	M
1921-22	M	M	M	M	M	M	M	M	M	M	M	M	M
1922-23	M	M	M	M	3.25	4.05	3.95	2.05	2.40	3.31	0.30	M	M
1923-24	M	M	M	M	M	M	M	M	M	M	M	M	M
1924-25	M	M	M	M	M	9.12	0.89	1.75	3.50	3.75	1.87	3.00	M
1925-26	M	M	M	5.25	M	1.25	3.00	9.10	1.75	14.15	0.25	M	M
1926-27	0	0	0	0	2.88	6.63	1.00	15.75	3.88	1.50	1.25	0.25	33.14
1927-28	0	0	0	2.00	2.00	4.54	1.20	3.25	1.95	0.20	0.75	0	15.89

M - Record missing.

Precipitation Station: Escondido Ditch Head #3   Elevation: 1,850 feet   Index No. 46B
Location: Sec. 33, T. 10 S., R. 1 E.,   Authority: Escondido Mutual Water   Not listed in Bulletin No. 48
S.B.B.&M.   Company

Season	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Seasonal Total
1929-30	M	0.09	1.27	0	0	0	8.49	1.50	4.55	2.67	7.23	0	M
1930-31	0	0	0	1.15	3.00	0	2.96	4.60	0.30	5.33	1.15	0	18.49
1931-32	0	0.72	0	M	M	M	4.56	14.53	1.38	2.38	0.90	0.67	M
1932-33	0	0	0	M	M	6.96	8.29	0.37	0.39	4.27	1.96	0	M
1933-34	0	0	M	M	M	4.37	1.97	5.22	0.73	0.88	0	0.96	M
1934-35	0	0.35	M	M	3.20	5.27	3.75	4.40	2.84	2.44	0.30	0	M
1935-36	0	2.95	0	0	1.02	0.91	0.45	10.22	3.39	1.01	0.43	0	20.38
1936-37	0.26	0.10	0.19	M	0.17	11.36	4.28	9.83	8.09	1.58	1.51	0	M
1937-38	0.13	0	0	0	0.11	3.98	3.85	8.06	12.15	2.42	0.94	0	31.64
1938-39	0	0.25	0	0.35	0.19	6.66	4.70	3.55	3.59	1.50	0.80	0	21.59
1939-40	0	0	3.45	0.45	1.23	1.13	6.74	6.26	4.04	2.44	0	0	25.74
1940-41	0	0	0	2.74	0.84	9.09	1.96	6.29	10.29	6.75	1.73	0.60	40.29
1941-42	0.85	0.46	0.13	3.52	3.50	5.85	0.37	5.10	3.44	3.51	0.07	0	26.80
1942-43	0	0.21	0	0.38	0.06	2.19	9.63	3.53	4.73	3.75	0.16	0	24.64
1943-44	0	0	0.06	0.81	0.06	7.75	1.33	9.05	3.06	1.30	0.59	1.06	25.07
1944-45	0	0	0	0	7.74	1.15	0.62	3.67	7.73	0.89	0.12	0.62	22.54
1945-46	0	1.80	0	0	0.81	6.71	0.91	1.65	4.54	2.64	1.12	0	20.18
1946-47	0	0	0	1.09	6.90	2.90	0.92	1.29	1.91	1.31	0.30	0.07	16.69
1947-48	0	0	0.53	0.53	0.88	3.63	0.10	2.56	3.56	1.75	0	0.12	13.66

M - Record missing.

Precipitation Station: Valley Center #3   Elevation: 1,550 feet   Index No. 48A
Location: Sec. 5, T. 11 S., R. 1 W.,   Authority: B. W. Leke   Not listed in Bulletin No. 48
S.B.B.&M.

Season	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Seasonal Total
1924-25	0	0	0	0.46	0.03	3.61	0.69	0.57	2.47	2.18	0.24	0.80	11.05
1925-26	0	0	0	5.40	2.30	1.30	1.75	3.84	0.74	10.04	0.10	0.07	25.54
1926-27	0	0	0	0.03	2.02	4.97	0.44	14.08	3.65	1.01	0.79	0.19	27.18
1927-28	0.04	0	0	2.93	0.18	5.02	0.87	3.25	1.35	0.19	0.71	0.06	14.60
1928-29	0	0	0	0.60	1.45	3.48	2.55	2.20	2.51	1.97	0	0	14.76
1929-30	0	0	0.63	0	0	0	8.06	1.08	3.85	2.57	4.29	0.02	20.50
1930-31	0.72	0	0	1.50	2.11	0	2.26	5.43	0.19	3.28	0.80	0	16.29
1931-32	0	0.68	0.03	1.32	3.57	7.39	3.47	10.60	0.39	0.42	0.07	0.31	28.25
1932-33	0	0	0	0	2.31	4.79	6.34	0.14	0.18	2.65	1.20	0.11	17.72
1933-34	0	0	0	0.17	0.19	3.57	0.95	3.13	0.61	0.29	0	0.88	9.79
1934-35	0	0.15	0.60	1.72	2.11	4.89	4.34	3.81	2.92	2.04	0.57	0	23.15
1935-36	0	1.40	0	0.25	0.95	0.52	0.59	7.76	2.71	0.88	0.11	0.05	15.22
1936-37	0.16	0.04	0.04	5.46	0.13	9.05	4.36	9.14	6.97	0.95	1.00	0.02	37.32
1937-38	0.24	0	0	0	0.13	2.31	3.09	4.77	12.42	1.56	0.36	0.05	24.93
1938-39	0	0	0	0.32	0	6.56	3.90	3.03	2.54	1.28	0.55	0	18.18
1939-40	0	0	4.76	0.30	0.85	0.79	5.40	4.66	2.79	1.27	0.14	0.24	21.20
1940-41	0	0	0.08	1.84	0.68	9.66	1.76	6.72	10.50	6.26	0.10	0.07	37.67
1941-42	M	M	0.19	2.82	3.07	4.01	0.78	3.79	3.00	2.83	0.05	0	M
1942-43	M	0.25	0	0.55	0.35	1.91	8.48	2.83	3.73	2.25	0.18	0.23	M
1943-44	M	M	M	M	0	7.35	0.97	6.12	1.69	0.90	0.18	0.68	M
1944-45	M	M	M	0	4.56	1.12	0.29	1.85	4.67	0.30	0.13	0.34	M
1945-46	0.06	2.98	0	0	0.43	6.60	Record discontinued						

M - Record missing.

Precipitation Station: Wohlford Lake
Location: Sec. 33, T. 11 S., R. 1 W.,
S.B.B.&M.

Elevation: 1,510 feet
Authority: Escondido Mutual Water Company

Index No. 49
Bulletin No. 48

Season	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Sea-sonal Total
1926-27	0	0	0	0	2.72	5.81	0.99	16.66	3.42	0.97	1.45	0.14	32.16
1927-28	0	0	0	1.35	2.65	5.64	0.77	2.75	1.15	0.10	0.60	0	15.01
1928-29	0	0.02	0	0.39	1.68	4.72	2.88	2.90	2.61	2.63	0	0	17.83
1929-30	0	0.22	0.80	0	0	0	7.80	1.33	3.36	0.94	7.03	0	21.48
1930-31	0.06	0	0.03	0.85	2.56	0	M	7.23	0.13	3.40	0.99	0	M
1931-32	0	0.45	0	1.35	4.21	7.64	2.22	11.75	0.33	1.01	0.11	0.52	29.59
1932-33	0	0	0	2.04	0	4.69	6.57	0.24	0.32	2.74	1.37	0.07	18.04
1933-34	0	0	0	0	0.34	3.44	2.27	3.55	1.35	0.25	0.04	0.66	11.90
1934-35	0	0	0.56	1.50	2.60	5.67	3.69	4.04	2.72	2.24	0.21	0	23.23
1935-36	0	0.28	0	0	0	0.53	0.52	9.36	2.22	1.12	0.12	0	14.15
1936-37	0	0.05	0	4.14	0.45	4.21	4.09	8.03	5.97	0.83	0.68	0	28.45
1937-38	0.10	0	0	0	0.20	2.12	2.36	7.73	10.95	1.56	0.27	0	25.29
1938-39	0.30	0	0	0.20	0.11	6.71	3.21	3.52	3.07	1.71	0.25	0	19.08
1939-40	0	0	3.05	0.55	0.75	0.75	5.75	5.43	0.41	4.29	0	0	20.98
1940-41	0	0	0.05	0.92	0.61	10.00	4.07	5.80	9.56	5.96	0.93	0.17	38.07
1941-42	0.09	0.45	0.19	2.66	2.86	5.68	0.91	4.41	2.24	3.56	0.06	0	23.11
1942-43	0	0.48	0	0.61	0.54	1.80	8.38	3.58	4.74	2.53	0.15	0.18	22.99
1943-44	0	0	0.18	0.41	0.06	6.32	1.55	6.37	1.98	1.18	0.61	0.78	19.44
1944-45	0	0	0.03	0	5.22	1.64	0.28	3.69	6.45	0.38	0.12	0.38	18.19
1945-46	0.05	2.51	0.04	0	0.57	7.76	0.69	1.62	4.75	0.75	0.51	0	19.25
1946-47	0	0	0	1.62	6.64	2.02	0.59	0.64	3.06	0.56	0.18	0.02	15.33
1947-48	0	0	0	0	0.80	3.62	0.04	1.88	1.32	2.77	0	0.65	11.08

M - Record missing.

Precipitation Station: Ramona #4
Location: Sec. 15, T. 13 S., R. 1 E.,
S.B.B.&M.

Elevation: 1,450 feet
Authority: U. C. Upjohn

Index No. 53A
Not listed in Bulletin No. 48

Season	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Sea-sonal Total
1942-43	0	0.13	0	0.50	0.46	2.25	5.96	2.77	5.96	0.21	0	0	18.24
1943-44	0	0	0.41	0.52	0.03	5.54	2.06	5.82	2.39	1.18	0.39	0.24	18.58
1944-45	0	0.03	0	0	5.31	1.24	0.16	2.38	5.44	0.29	0.10	0.11	15.06
1945-46	0	1.57	0.13	0	0.50	6.76	0.82	1.05	2.79	0.73	0.16	0	14.51
1946-47	0	0	0	1.45	3.72	1.63	0.51	0.69	1.96	0.44	0.15	0.05	10.60
1947-48	0	0.09	0.23	0.44	0.52	2.96	0.03	2.02	2.45	0.90	0.03	0.60	10.27

Precipitation Station: Bernardo Bridge
Location: Sec. 10, T. 13 S., R. 2 W.,
S.B.B.&M.

Elevation: 350 feet
Authority: City of San Diego

Index No. 58
Bulletin No. 48

Season	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Sea-sonal Total
1933-34	0	0.10	0	0.26	0.45	2.33	0.46	2.47	0.87	0.02	0	0.45	7.41
1934-35	0	0	0.19	1.22	2.00	4.55	3.27	4.63	2.10	1.54	0.10	0	19.60
1935-36	0	0.14	0	0	0.98	0.91	0.78	6.48	2.52	0.37	0	0	12.18
1936-37	0	0	0	4.96	0.50	9.63	3.44	9.17	5.34	0.58	0.24	0	33.86
1937-38	0.10	0	0	0	0.14	2.21	2.10	4.48	6.00	1.00	0.19	0.05	16.27
1938-39	0.10	0	0	0.10	0	6.36	3.33	1.87	0.90	0.83	0.08	0	13.57
1939-40	0	0	3.75	0.50	0.54	0.67	4.69	4.70	0.11	4.14	0	0	19.10
1940-41	0	0	0	1.97	0.53	6.71	4.69	4.16	7.67	5.76	0.69	0	32.18
1941-42	0.04	0.04	0.13	2.61	2.67	5.98	0.93	2.04	1.90	2.52	0.04	0	18.90
1942-43	0	0.17	0	0.51	0.19	1.81	0.59	1.72	4.26	1.82	0	0	17.07
1943-44	0	0	0	0.30	0.06	6.94	1.10	5.01	1.58	1.31	0.18	0.10	16.58
1944-45	0	0	0	0	5.58	1.57	0.13	2.42	5.66	0.15	0.02	0.08	15.61
1945-46	0.03	1.56	0.15	0	0.46	5.51	0.75	0.81	2.80	0.55	0.04	0	12.66
1946-47	0	0	0.03	0.81	3.85	1.35	0.30	0.53	2.69	0.25	0	0	9.81
1947-48	0	0	0.05	0.60	1.47	3.16	0.02	1.83	2.41	0.54	0	0.36	10.44

Additional record published in Bulletin No. 48.

Precipitation Station: Hodges Dam   Elevation: 350 feet   Index No. 60
Location: Sec. 18, T. 13 S., R. 2 W.,   Authority: City of San Diego   Bulletin No. 48
           S.B.S.&M.

Season	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Sea-sonal Total
1933-34	0	0.13	0	0.17	0.42	2.44	1.19	2.82	0.75	0.08	0	0.80	8.80
1934-35	0	0.14	0.31	1.36	2.45	4.18	3.07	4.15	2.15	1.52	0.24	0	19.57
1935-36	0	0.20	0.04	0.22	0.84	0.87	0.71	6.28	1.85	0.56	0.03	0.03	11.63
1936-37	0.05	0	0.06	4.95	0.51	9.18	3.08	8.69	5.16	0.58	0.66	0	32.92
1937-38	0.12	0	0	0	0.10	2.11	1.34	5.67	6.99	0.86	0.34	0.11	17.64
1938-39	0	0.03	0	4.97	0.08	5.33	3.31	1.68	1.79	0.85	0.05	0	18.09
1939-40	0	0	3.35	0.51	0.29	0.52	4.80	5.25	0.32	3.15	0	0	18.19
1940-41	0	0	0.04	1.17	0.38	5.60	1.94	4.96	6.74	5.22	0.80	0	26.85
1941-42	0.02	0	0.15	2.99	2.57	6.29	0.78	2.16	1.53	2.51	0.08	0	19.08
1942-43	0	0.12	0	0.46	0.25	1.98	7.24	1.62	3.20	1.82	0.03	0.13	16.85
1943-44	0	0	0.02	0.26	0.03	7.76	1.04	4.28	1.34	0.89	0.12	0.43	16.17
1944-45	0	0	0.05	0	5.33	1.46	0.06	2.47	5.21	0.10	0	0.08	14.76
1945-46	0	1.96	0.10	0	0.39	4.99	1.00	1.06	3.05	0.46	0.08	0	13.09
1946-47	0	0	0	1.06	3.92	1.62	0.30	0.59	2.53	0.42	0.09	0	10.53
1947-48	0	0	0.07	0.41	1.21	2.38	0	1.33	2.66	0.77	0	0.33	9.16

Additional record published in Bulletin No. 48.

Precipitation Station: San Dieguito Dam   Elevation: 250 feet   Index No. 61
Location: Sec. 16, T. 13 S., R. 3 W.,   Authority: City of San Diego   Bulletin No. 48
           S.B.B.&M.

Season	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Sea-sonal Total
1933-34	0	0.13	0	0.09	0.42	2.30	0.75	2.45	1.17	0.13	0	0.83	8.27
1934-35	0	0	0.44	1.25	2.05	3.85	3.09	4.79	2.09	1.32	0.21	0	19.09
1935-36	0	0.24	0.03	0.25	0.83	0.86	0.86	6.39	1.41	0.47	0.05	0	11.39
1936-37	0.10	0.05	0.03	3.66	0.54	8.13	2.69	6.28	5.23	0.54	0.51	0.04	27.80
1937-38	0.08	0	0	0	0.03	1.85	1.04	5.36	5.71	0.72	0.32	0.16	15.27
1938-39	0	0.04	0	0.05	0.01	4.49	2.61	1.46	1.61	0.50	0.07	0	10.84
1939-40	0	0	2.41	0.32	0.27	0.50	3.40	5.16	0.23	3.21	0	0	15.50
1940-41	0	0	0.02	1.04	1.76	5.45	2.16	4.35	6.46	4.94	0.60	0	26.78
1941-42	0.02	0	0.17	2.72	2.41	5.83	0.70	2.71	1.34	1.78	0.05	0	17.73
1942-43	0	0.06	0	0.46	0.26	1.25	6.13	1.27	2.23	1.80	0	0.20	13.66
1943-44	0	0	0.03	0.32	0.04	7.79	1.54	3.83	1.29	0.93	0.07	0.31	16.15
1944-45	0	0	0.06	0	5.10	1.52	0.04	2.03	4.23	0.06	0.07	0.10	13.21
1945-46	0	1.41	0.09	0.11	0.71	4.80	0.71	0.90	2.35	0.59	0.14	0	11.81
1946-47	0	0	0.02	0.52	4.47	1.85	0.48	0.64	1.88	0.17	0.07	0.01	10.11
1947-48	0	0	0.15	0.30	0.64	2.31	0	1.23	2.08	0.71	0	0.40	7.82

Additional record published in Bulletin No. 48.

Precipitation Station: Miramar
Location: Sec. 5, T. 15 S., R. 2 W., S.B.B.&M.
Elevation: 660 feet
Authority: G. A. Riley, S. G. Erro and B. E. Hendrix
Index No. 64
Bulletin No. 48

Season	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Seasonal Total
1934-35	0	0	0	0.80	1.81	4.85	2.94	5.66	2.34	1.78	0	0	20.18
1935-36	0	0.15	0	0	2.15	0.83	1.23	7.75	1.69	0.34	0.56	0	14.70
1936-37	0	0	0	3.17	0.50	7.29	2.76	6.70	4.45	1.47	0	0	26.34
1937-38	0	0	0	0.15	0	2.35	1.95	5.73	5.60	0.70	0	0	16.48
1938-39	0	0	0	0	0	4.70	3.52	2.30	2.00	0.45	0	0	12.97
1939-40	0	0	5.55	1.10	0.20	0.65	3.75	4.78	2.10	0.80	0	0	18.93
1940-41	0	0	0	1.65	0.75	6.15	1.85	4.90	7.70	6.75	0	0	29.75
1941-42	0	0	0.32	3.10	2.10	3.67	0.85	3.50	1.50	0.75	0	0	15.79
1942-43	0	0	0	0	1.80	1.42	6.10	2.70	3.15	2.45	0	0	17.62
1943-44	0	0	0	0.80	0	7.85	0.75	5.05	1.60	1.10	0.25	0	17.40
1944-45	0	0	0	0	4.05	1.65	0.65	2.60	4.20	0	0	0.15	13.30
1945-46	0	1.40	0	0	0.65	5.50	1.05	3.35	3.30	0.48	0	0	15.73
1946-47	0	0	0	1.55	3.27	1.40	0.63	0.23	1.06	0	0	0	8.14
1947-48	0	0	0	0.74	1.48	4.18	0	1.65	1.89	0.50	0.04	0.20	10.68

Additional record published in Bulletin No. 48.

Precipitation Station: Diverting Dam
Location: Sec. 11, T. 14 S., R. 2 E., S.B.B.&M.
Elevation: 840 feet
Authority: La Mesa, Lemon Grove and Spring Valley Irrigation District
Index No. 96
Bulletin No. 48

Season	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Seasonal Total
1933-34	0	0	0	0.22	0.69	2.51	0.81	2.28	0.80	0.08	0	0.30	7.69
1934-35	0	0	0.09	0.41	1.03	2.42	3.04	5.70	2.71	2.66	0	0	18.06
1935-36	0	0.23	0.15	0.10	0.80	0.76	0.37	8.63	3.45	1.23	0	0	15.72
1936-37	0.16	0.18	0	1.84	0.41	7.96	4.39	8.68	4.38	0.71	0	0	28.71
1937-38	0.07	0	0	0	0	2.14	2.23	5.95	7.13	1.18	0.41	0	19.11
1938-39	0	0.18	0	0.28	0.04	6.83	3.52	2.96	1.94	0.47	0.12	0	16.34

Record discontinued

Additional record published in Bulletin No. 48.

Precipitation Station: Holdredge Ranch
Location: Sec. 22, T. 11 S., R. 2 E., S.B.B.&M.
Elevation: 3,480 feet
Authority: F. E. Holdredge
Index No. 132
Not listed in Bulletin No. 48

Season	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Seasonal Total
1934-35	M	M	M	M	M	M	6.10	5.78	4.96	4.42	0.25	0	M
1935-36	0	1.18	1.30	0.58	1.18	2.12	0.77	20.57	5.56	3.46	0	0	36.67
1936-37	0	0	0	4.27	0.10	17.97	7.90	18.24	9.89	2.38	1.41	0	62.16
1937-38	0	0	0	0.55	6.66	4.49	13.75	13.43	2.58	2.69	0	0	44.15
1938-39	0	0	0	0	0.64	10.87	6.70	6.37	4.82	2.58	0.10	0	32.08
1939-40	0	0	7.32	0.98	1.71	1.74	8.43	8.59	0.90	2.61	0	0	32.28
1940-41	0	0	0	3.39	0.12	0	3.50	10.64	9.68	8.93	0.67	0	36.93
1941-42	0	0	0	4.93	4.09	18.06	0.73	5.18	3.70	3.82	0	0	40.51
1942-43	0	0	0	1.15	1.25	3.17	13.38	4.78	7.63	5.18	0	0	36.54
1943-44	0	0	0	1.21	0	8.26	3.29	12.24	4.16	2.87	0.41	0.95	33.39
1944-45	0	0	0	0	9.21	2.18	1.72	4.96	13.09	1.08	0.16	0.68	33.08
1945-46	0	4.03	0	0.38	3.22	15.42	3.68	0.61	5.61	1.17	1.05	0	35.17
1946-47	0	0	1.03	3.17	9.64	3.23	2.43	1.67	3.59	1.57	0.92	0.09	27.34
1947-48	0	0	0.66	0.63	1.56	5.24	0.17	4.81	5.97	2.81	0.03	0.76	22.64

M - Record missing.

APPENDIX F

ESTIMATED OR MEASURED ACTUAL MONTHLY RUNOFF
AT KEY GAGING STATIONS
IN SAN DIEGUITO BASIN

1912-13 to 1947-48, Inclusive

ESTIMATED OR MEASURED ACTUAL MONTHLY RUNOFF
AT KEY GAGING STATIONS
IN SAN DIEGUITO BASIN

1912-13 to 1947-48, Inclusive

in Acre-Feet

Season and Month	At Sutherland Dam Site Station No. 23	At Pamo Dam Site Station No. 26	At Hodges Dam Station No. 33
1912-13			
Oct.	193[a]	264	0[b]
Nov.	100[a]	142	12
Dec.	110[a]	232	12
Jan.	369	472	12
Feb.	866	1,350	310
Mar.	1,450	1,780	1,390
Apr.	708	916	320
May	456	442	8
June	213	155	3
July	40	12	0
Aug.	9	6	0
Sept.	4	11	0
Totals	4,524	5,782	2,067

Season and Month	At Sutherland Dam Site Station No. 23	At Pamo Dam Site Station No. 26	At Hodges Dam Station No. 33
1915-16			
Oct.	130	169	0[b]
Nov.	220	360	0[b]
Dec.	438	750	441[b]
Jan.	66,400	104,000	257,000
Feb.	11,600	19,800	24,800
Mar	7,810	11,200	16,300
Apr.	4,090	6,070	6,720
May	2,140	3,340	3,320
June	1,140	1,680	1,200
July	592	916	290
Aug.	268	646	0
Sept.	420	512	0
Totals	95,248	149,443	310,071

1913-14			
Oct.	15	6	0[b]
Nov.	105	198	0
Dec.	207	279	2
Jan.	3,090	5,070	4,390
Feb.	3,550	8,500	12,765
Mar.	1,450	2,490	2,400
Apr.	964	1,620	1,200
May.	695	1,100	695
June	314	522	24
July	46	20	0
Aug.	3	6	0
Sept.	11	6	0
Totals	10,450	19,817	21,486

1916-17			
Oct.	484	1,040	1,590
Nov.	383	762	666
Dec.	701	1,860	3,060
Jan.	1,880	3,540	7,620
Feb.	3,450	7,220	8,330
Mar.	2,510	3,640	4,650
Apr.	1,580	2,760	3,520
May	1,320	2,020	2,020
June	774	791	552
July	337	348	0
Aug.	167	164	0
Sept.	134	187	0
Totals	13,720	24,332	32,008

1914-15			
Oct.	48	35	0[b]
Nov.	76	125	0
Dec.	270	397	0
Jan.	2,230	4,320	6,509
Feb.	8,660	14,400	26,296
Mar.	4,910	7,500	9,644
Apr.	2,640	4,860	8,687
May	9,220	13,600	20,557
June	2,050	2,800	1,760
July	615	959	54
Aug.	232	569	53
Sept.	183	232	0
Totals	31,134	49,797	73,560

1917-18			
Oct.	74	152	0
Nov.	155	305	6
Dec.	128	311	9
Jan.	221	738	261
Feb.	349	905	1,100
Mar.	3,990	7,810	22,400
Apr.	988	1,240	1,570
May	744	614	212
June	425	138	14
July	96	87	0
Aug.	98	77	0
Sept.	87	66	0
Totals	7,355	12,443	25,572

Season and Month	At Sutherland Dam Site Station No. 23	At Pamo Dam Site Station No. 26	At Hodges Dam Station No. 33

1918-19

Season and Month	At Sutherland Dam Site Station No. 23	At Pamo Dam Site Station No. 26	At Hodges Dam Station No. 33
Oct.	127	175	0
Nov.	327	446	111
Dec.	560	738	117
Jan.	358	483	93
Feb.	928	961	989
Mar.	1,440	1,690	1,689
Apr.	643	839	380
May	312	443	23
June	60	57	0
July	12	5	0
Aug.	9	6	25
Sept.	36	25	7
Totals	4,812	5,868	3,434

1919-20

Season and Month	At Sutherland Dam Site Station No. 23	At Pamo Dam Site Station No. 26	At Hodges Dam Station No. 33
Oct.	64	28	50
Nov.	261	175	35
Dec.	438	338	48
Jan.	251	283	44
Feb.	1,370	2,340	1,678
Mar.	5,040	7,190	8,283
Apr.	2,980	4,770	3,838
May	1,370	1,730	493
June	375	546	2
July	87	98	39
Aug.	253	42	37
Sept.	30	14	0
Totals	12,519	17,554	14,547

1920-21

Season and Month	At Sutherland Dam Site Station No. 23	At Pamo Dam Site Station No. 26	At Hodges Dam Station No. 33
Oct.	102	71	39
Nov.	168	150	58
Dec.	231	287	51
Jan.	434	652	133
Feb.	415	528	91
Mar.	646	1,010	697
Apr.	318	355	104
May	596	793	227
June	242	215	0
July	19	10	56
Aug.	0	0	10
Sept.	0	0	19
Totals	3,171	4,071	1,485

1921-22

Season and Month	At Sutherland Dam Site Station No. 23	At Pamo Dam Site Station No. 26	At Hodges Dam Station No. 33
Oct.	65	39	12
Nov.	54	39	41
Dec.	11,400	20,300	35,918
Jan.	5,530	9,410	13,240
Feb.	10,400	17,100	27,485
Mar.	9,280	15,300	24,357
Apr.	5,370	9,100	10,663
May	2,940	5,130	4,678
June	1,310	1,980	1,330
July	500	818	325
Aug.	213	294	68
Sept.	97	149	240
Totals	47,159	79,659	118,357

1922-23

Season and Month	At Sutherland Dam Site Station No. 23	At Pamo Dam Site Station No. 26	At Hodges Dam Station No. 33
Oct.	129	248	175
Nov.	317	581	209
Dec.	1,380	2,390	2,663
Jan.	824	1,540	1,862
Feb.	2,420	3,870[c]	4,815
Mar.	1,650	2,640[c]	3,047
Apr.	1,610	2,576[c]	2,248
May	719	1,150[c]	440
June	332	530[c]	177
July	90	140[c]	210
Aug.	50	80[c]	186
Sept.	38	60[c]	78
Totals	9,559	15,805	16,110

1923-24

Season and Month	At Sutherland Dam Site Station No. 23	At Pamo Dam Site Station No. 26	At Hodges Dam Station No. 33
Oct.	74	118[c]	24
Nov.	122	195	63
Dec.	230	368	83
Jan.	261	418	92
Feb.	139	222	102
Mar.	861	1,378	2,056
Apr.	791	1,266	1,674
May	227	363	149
June	36	58	101
July	0	0	236
Aug.	0	0	171
Sept.	0	0	0
Totals	2,741	4,386	4,751

ESTIMATED OR MEASURED ACTUAL MONTHLY RUNOFF
AT KEY GAGING STATIONS
IN SAN DIEGUITO BASIN (continued)

1912-13 to 1947-48, Inclusive

in Acre-Feet

Season and Month	At Sutherland Dam Site Station No. 23	At Pamo Dam Site Station No.26	At Hodges Dam Station No. 33

1924-25

	At Sutherland Dam Site Station No. 23	At Pamo Dam Site Station No.26	At Hodges Dam Station No. 33
Oct.	6	c 10	39
Nov.	71	114	0
Dec.	615	984	200
Jan.	316	506	72
Feb.	265	424	87
Mar.	386	618	88
Apr.	1,100	1,760	1,122
May	363	581	105
June	336	538	18
July	11	18	0
Aug.	0	0	0
Sept.	0	0	0
Totals	3,469	5,553	1,731

1925-26

Oct.	163	c 261	71
Nov.	178	285	29
Dec.	201	322	45
Jan.	167	267	0
Feb.	1,190	1,904	2,498
Mar.	402	643	331
Apr.	11,300	18,080	30,139
May	1,290	2,064	1,147
June	361	578	0
July	74	118	5
Aug.	12	19	83
Sept.	3	5	0
Totals	15,341	24,546	34,348

1926-27

Oct.	25	c 40	0
Nov.	114	182	0
Dec.	2,070	3,312	1,210
Jan.	866	1,386	864
Feb.	30,800	49,280	126,630
Mar.	8,200	13,120	15,167
Apr.	3,680	5,888	8,196
May.	2,050	3,280	3,801
June	1,140	1,824	831
July	248	397	0
Aug.	147	235	0
Sept.	207	331	0
Totals	49,547	79,275	156,699

Season and Month	At Sutherland Dam Site Station No. 23	At Pamo Dam Site Station No. 26	At Hodges Dam Station No. 33

1927-28

	At Sutherland Dam Site Station No. 23	At Pamo Dam Site Station No. 26	At Hodges Dam Station No. 33
Oct.	185	c 296	29
Nov.	210	336	67
Dec.	566	906	1,752
Jan.	507	811	1,553
Feb.	785	1,256	3,496
Mar.	617	987	1,552
Apr.	402	643	277
May	281	450	144
June	71	114	0
July	0	0	0
Aug.	0	0	13
Sept.	0	0	21
Totals	3,624	5,799	8,904

1928-29

Oct.	a 0	c 0	0
Nov.	204	326	0
Dec.	188	301	271
Jan.	430	688	269
Feb.	797	1,275	1,824
Mar.	1,075	1,720	2,252
Apr.	1,537	2,459	3,531
May	434	694	239
June	165	264	0
July	13	21	102
Aug.	0	0	10
Sept.	47	75	0
Totals	4,890	7,823	8,498

1929-30

Oct.	a 8	c 13	0
Nov.	26	42	0
Dec.	27	43	26
Jan.	1,026	1,642	1,021
Feb.	561	898	749
Mar.	1,938	3,101	5,054
Apr.	1,031	1,650	837
May	2,650	4,240	7,704
June	563	901	76
July	145	232	0
Aug.	30	48	0
Sept.	8	13	0
Totals	8,013	12,823	15,467

Season and Month	At Sutherland Dam Site Station No. 23	At Pamo Dam Site Station No. 26	At Hodges Dam Station No. 33

1930-31

Season and Month	At Sutherland Dam Site Station No. 23	At Pamo Dam Site Station No. 26	At Hodges Dam Station No. 33
Oct.	a 64	c 102	0
Nov.	278	445	0
Dec.	185	296	0
Jan.	278	445	198
Feb.	1,388	2,221	3,826
Mar.	350	560	326
Apr.	281	450	285
May	250	400	176
June	20	32	0
July	0	0	0
Aug.	0	0	0
Sept.	0	0	0
Totals	3,094	4,951	4,811

1931-32

Season and Month	At Sutherland Dam Site Station No. 23	At Pamo Dam Site Station No. 26	At Hodges Dam Station No. 33
Oct.	a 8	c 13	d 0
Nov.	104	166	1
Dec.	1,348	2,157	4,078
Jan.	1,152	1,843	2,873
Feb.	21,283	34,053	49,870
Mar.	3,979	6,366	10,092
Apr.	1,599	2,558	2,594
May	976	1,562	1,637
June	553	885	171
July	194	310	0
Aug.	53	85	0
Sept.	30	48	0
Totals	31,279	50,046	71,316

1932-33

Season and Month	At Sutherland Dam Site Station No. 23	At Pamo Dam Site Station No. 26	At Hodges Dam Station No. 33
Oct.	a 101	c 162	88
Nov.	64	102	41
Dec.	354	566	1,261
Jan.	2,003	3,205	7,375
Feb.	1,557	2,491	3,821
Mar.	879	1,406	702
Apr.	702	1,123	1,231
May	1,307	2,091	2,649
June	490	784	113
July	105	168	0
Aug.	27	43	0
Sept.	14	22	0
Totals	7,603	12,163	17,281

1933-34

Season and Month	At Sutherland Dam Site Station No. 23	At Pamo Dam Site Station No. 26	At Hodges Dam Station No. 33
Oct.	a 12	c 19	36
Nov.	25	40	40
Dec.	200	320	414
Jan.	313	501	269
Feb.	252	403	505
Mar.	255	408	201
Apr.	116	186	13
May	3	5	0
June	0	0	72
July	0	0	0
Aug.	0	0	0
Sept.	0	0	0
Totals	1,176	1,882	1,550

1934-35

Season and Month	At Sutherland Dam Site Station No. 23	At Pamo Dam Site Station No. 26	At Hodges Dam Station No. 33
Oct.	a 0	c 0	258
Nov.	71	114	276
Dec.	290	464	768
Jan.	824	1,318	680
Feb.	922	1,475	3,040
Mar.	1,400	2,240	2,400
Apr.	750	1,200	970
May	330	528	129
June	51	82	0
July	0	0	0
Aug.	0	0	0
Sept.	0	0	0
Totals	4,638	7,421	8,521

1935-36

Season and Month	At Sutherland Dam Site Station No. 23	At Pamo Dam Site Station No. 26	At Hodges Dam Station No. 33
Oct.	a 0	c 0	0
Nov.	0	0	77
Dec.	20	32	120
Jan.	96	154	99
Feb.	2,609	4,174	5,160
Mar.	926	1,482	1,560
Apr.	1,981	3,170	3,930
May	516	826	30
June	64	102	0
July	96	154	77
Aug.	19	30	0
Sept.	6	10	0
Totals	6,333	10,134	11,053

ESTIMATED OR MEASURED ACTUAL MONTHLY RUNOFF
AT KEY GAGING STATIONS
IN SAN DIEGUITO BASIN (continued)

1912-13 to 1947-48, Inclusive

in Acre-Feet

Season and Month	At Sutherland Dam Site Station No. 23	At Pamo Dam Site Station No. 26	At Hodges Dam Station No. 33

1936-37

Oct.	0	c 0	1,110
Nov.	30	48	66
Dec.	2,010	3,216	6,740
Jan.	3,610	5,776	10,200
Feb.	22,350	35,760	72,160
Mar.	10,880	17,408	47,560
Apr.	5,010	8,016	18,100
May	2,220	3,552	5,100
June	983	1,573	1,830
July	348	557	0
Aug.	92	147	0
Sept.	37	59	0
Totals	47,570	76,112	162,866

1937-38

Oct.	51	c 82	0
Nov.	83	133	46
Dec.	337	539	425
Jan.	461	738	1,070
Feb.	1,960	3,136	8,050
Mar.	20,310	32,496	70,600
Apr.	3,190	5,104	6,530
May	1,920	3,072	3,850
June	861	1,378	854
July	317	507	25
Aug.	102	163	81
Sept.	43	69	30
Totals	29,635	47,417	91,561

1938-39

Oct.	88	c 141	0
Nov.	129	206	19
Dec.	864	1,382	4,951
Jan.	1,070	1,712	5,046
Feb.	4,010	6,416	15,662
Mar.	2,100	3,360	8,906
Apr.	1,490	2,384	4,432
May	706	1,130	680
June	215	344	41
July	49	78	0
Aug.	1	2	0
Sept.	125	200	408
Totals	10,847	17,355	40,145

Season and Month	At Sutherland Dam Site Station No. 23	At Pamo Dam Site Station No. 26	At Hodges Dam Station No. 33

1939-40

Oct.	90	c 144	35
Nov.	130	208	37
Dec.	161	258	138
Jan.	681	1,090	2,080
Feb.	1,890	3,024	6,550
Mar.	1,040	1,664	2,550
Apr.	2,360	3,776	6,400
May	497	795	281
June	119	190	0
July	9	14	0
Aug.	0	0	0
Sept.	0	0	0
Totals	6,977	11,163	18,071

1940-41

Oct.	35	c 56	56
Nov.	99	158	53
Dec.	2,470	3,952	10,260
Jan.	1,270	2,032	6,090
Feb.	3,910	6,256	17,220
Mar.	15,100	24,160	56,330
Apr.	13,830	22,128	56,020
May	3,760	6,016	22,120
June	1,420	2,272	10,400
July	596	954	604
Aug.	338	541	84
Sept.	186	298	15
Totals	43,014	68,823	179,252

1941-42

Oct.	454	c 726	1,460
Nov.	465	744	2,800
Dec.	960	1,536	10,020
Jan.	1,770	2,832	8,930
Feb.	1,210	1,936	4,850
Mar.	1,670	2,672	6,960
Apr.	1,360	2,176	3,250
May	857	1,371	1,150
June	308	493	146
July	60	96	0
Aug.	2	3	0
Sept.	0	0	0
Totals	9,116	14,585	39,566

ESTIMATED OR MEASURED ACTUAL MONTHLY RUNOFF
AT KEY GAGING STATIONS
IN SAN DIEGUITO BASIN (continued)

1912-13 to 1947-48, Inclusive

in Acre-Feet

Season and Month	At Sutherland Dam Site Station No. 23	At Pamo Dam Site Station No. 26	At Hodges Dam Station No. 33

1942-43

Season and Month	At Sutherland Dam Site Station No. 23	At Pamo Dam Site Station No. 26	At Hodges Dam Station No. 33
Oct.	34	c 54	46
Nov.	86	138	21
Dec.	198	317	268
Jan.	2,870	4,592	10,470
Feb.	1,880	3,008	4,440
Mar.	5,620	8,992	19,610
Apr.	5,080	8,128	10,020
May	1,500	2,400	1,660
June	586	938	162
July	140	224	0
Aug.	26	42	0
Sept.	1	2	2
Totals	18,021	28,835	46,699

1943-44

Season and Month	At Sutherland Dam Site Station No. 23	At Pamo Dam Site Station No. 26	At Hodges Dam Station No. 33
Oct.	42	54	27
Nov.	87	124	4
Dec.	493	708	1,150
Jan.	499	738	1,360
Feb.	3,760	6,160	9,600
Mar.	4,680	6,970	5,650
Apr.	1,700	2,310	3,230
May	964	1,270	880
June	558	841	259
July	111	197	0
Aug.	12	20	0
Sept.	0	5	15
Totals	12,906	19,397	22,175

1944-45

Season and Month	At Sutherland Dam Site Station No. 23	At Pamo Dam Site Station No. 26	At Hodges Dam Station No. 33
Oct.	3	12	0
Nov.	493	802	899
Dec.	305	424	584
Jan.	277	433	602
Feb.	764	1,250	1,940
Mar.	4,340	6,880	10,740
Apr.	2,010	2,760	2,760
May	756	988	257
June	373	487	6
July	51	64	0
Aug.	198	211	0
Sept.	64	62	0
Totals	9,634	14,373	17,788

1945-46

Season and Month	At Sutherland Dam Site Station No. 23	At Pamo Dam Site Station No. 26	At Hodges Dam Station No. 33
Oct.	57	53	0
Nov.	107	126	0
Dec.	3,380	5,280	9,920
Jan.	980	1,280	1,830
Feb.	571	795	1,230
Mar.	833	1,160	1,750
Apr.	854	1,300	1,650
May	332	476	0
June	30	59	0
July	0	0	0
Aug.	0	0	0
Sept.	22	0	57
Totals	7,166	10,529	16,437

1946-47

Season and Month	At Sutherland Dam Site Station No. 23	At Pamo Dam Site Station No. 26	At Hodges Dam Station No. 33
Oct.	45	30	e 18
Nov.	739	1,030	457
Dec.	364	579	339
Jan.	321	481	145
Feb.	319	446	324
Mar.	442	668	1,035
Apr.	222	403	104
May	36	68	- 164
June	5	8	- 226
July	0	0	- 236
Aug.	0	0	- 199
Sept.	0	0	- 153
Totals	2,493	3,713	1,444

1947-48

Season and Month	At Sutherland Dam Site Station No. 23	At Pamo Dam Site Station No. 26	At Hodges Dam Station No. 33
Oct.	0	0	e - 104
Nov.	8	3	- 56
Dec.	127	145	308
Jan.	71	105	- 69
Feb.	243	377	37
Mar.	339	455	106
Apr.	341	405	- 72
May	52	86	- 60
June	23	28	- 57
July	0	0	- 77
Aug.	0	0	- 120
Sept.	0	0	- 111
Totals	1,204	1,604	- 275

Runoff at Pamo dam site for the period February 1923 to September 1943, inclusive, is estimated by the Division of Water Resources. Remaining values are from records of the United States Geological Survey, except as noted:

a - Observed or estimated by F. E. Green, City of San Diego.

b - Runoff between Bernardo and Hodges Dam estimated by Division of Water Resources, and added to Bernardo runoff.

c - Estimated by Division of Water Resources.

d - Corrected by Division of Water Resources for rainfall on reservoir surface, as was done by United States Geological Survey for remaining seasons.

e - Notation by United States Geological Survey, "For months when inflow to the reservoir was small and other elements were large, negative or discordant figures of runoff may appear. To the extent that such discrepancies may be attributed to changes in reservoir capacity since the time of the rating used, or to uncertanties in the rating, quantities too small for periods of falling stage in the reservoir are compensated by quantities too large for periods of corresponding rising stage."

APPENDIX G

DATA REGARDING SPECIAL CENSUS

San Francisco Office
307 Customhouse   Regional Office

March 29, 1949

Mr. Edward Hyatt, State Engineer,
Division of Water Resources,
Public Works Building,
P. O. Box 1079,
Sacramento 5, California

                        Attention: Mr. P. H. Van Etten,
                                    Principal Hydraulic Engineer

Dear Mr. Hyatt:

In further reference to your letter of March 7 and our reply
of March 14, we now have a letter from the Bureau of the Census
(Howard G. Brunsman, Chief, Population Division), Washington,
reading as follows:

        "In special censuses, the military and naval personnel
    stationed in the area is included in its population, in ac-
    cordance with the marked paragraphs of the enclosed instruc-
    tions to Enumerators for Special Censuses. This practice is
    similar to the procedure followed in the 1940 decennial census.
    Therefore, the population figure of 362,658 does include mem-
    bers of the armed forces stationed in San Diego on the census
    date. The separate population of the military establishments
    in the city, according to the special census was 72,209. This
    figure comprises only those persons living in such establishments.
    We are unable to furnish figures for members of the armed forces
    living off post."

We are enclosing the release, "Instructions to Enumerators for
Special Censuses", mentioned above. If you could take off the
data you need from it and return it for our files, it would be
very much appreciated.

                        Very truly yours,

                        /s/ John J. Judge,

                            John J. Judge,
                            Regional Director.

Extracts from
"Instructions to Enumerators for Special Censuses"

"Who is to be enumerated.--The persons to be enumerated in each dwelling unit include all persons whether civilian or members of the armed forces, who were living in this dwelling unit at the time of the interview, except that babies born after 12.01 A.M. of the census day should be omitted and persons dying after this time should be included in the census."

"Enumeration of members of the armed forces.--Persons who are in the Army, Navy, Marine Corps, or Coast Guard are to be counted as now living in this dwelling unit only if they are stationed in this area and living off post in this dwelling unit."

"Absent persons who are not to be enumerated as now living in the dwelling unit.--Below are listed certain types of persons whom the respondent may consider as still being members of his household but who are actually not to be enumerated as now living in this dwelling unit:

(a) Do not include men and women now stationed elsewhere with the armed forces (Army, Navy, Coast Guard, or the Marine Corps) even though home on leave, furlough, or pass at the time of the enumeration."

APPENDIX H

ESTIMATES OF COSTS

ESTIMATED COSTS OF COMPLETING SUTHERLAND RESERVOIR

(Based upon Prices Prevailing in April 1947)

Elevation of crest of dam:
2,074 feet, U.S.G.S. datum.
Elevation of crest of fixed spillway:
2,056 feet.
Height of dam to crest of drum gates,
above streambed: 158 feet.

Capacity of reservoir to crest of
drum gates (elevation 2,070 feet):
36,724 acre-feet.
Capacity of spillway:
37,000 second-feet.

Item	Quantity	Unit Price	Cost	
Dam (including spillway)				
Diversion and care of river	$ lump sum	$	2,000	
Excavation				
Spillway, rock	22,000 cu.yds.	4.00	88,000	
Cutoff, rock	1,000 cu.yds.	8.00	8,000	
Concrete, reinforced				
Cutoff	2,200 cu.yds.	30.00	66,000	
Buttresses	15,600 cu.yds.	21.00	327,600	
Arches	11,800 cu.yds.	30.00	354,000	
Bridge and struts	3,115 cu.yds.	60.00	186,900	
Spillway structure and walls	3,600 cu.yds.	50.00	180,000	
Spillway paving	1,700 cu.yds.	27.00	45,900	
Reinforcing steel	3,360,000 lbs.	0.11	369,600	
Drum gates, 13 x 50 feet	3 each	32,000	96,000	$1,724,000
Outlet Works				
Concrete				
Mass, in pipe anchors and pipes	100 cu.yds.	20.00	2,000	
Reinforced	356 cu.yds.	60.00	21,400	
Trash rack bars	32,000 lbs.	0.15	4,800	
Structural steel	10,000 lbs.	0.20	2,000	
Tractor gate end hoist	2 each	8,000	16,000	
Tube valve, 48-inch diameter	1 each	15,000	15,000	
Steel pipe, 48-inch diameter	42,000 lbs.	0.25	10,500	71,700
Reservoir				
Land and improvements	360 acres		2,500	
Clearing reservoir lands	660 acres	30.00	19,800	22,300
Subtotal -				$1,818,000
Administration and engineering	10% (0.10 x 1,818,000)			181,800
Contingencies	15% (0.15 x 1,818,000)			272,700
Interest during construction	1 year at 3%			70,300
TOTAL -				$2,342,800

ANNUAL COST (based on capital cost to complete dam only)			
Interest	3%	$	70,300
Amortization	50-year sinking fund at 3% (0.00886)		20,700
Depreciation, dam	100-year life, 3% sinking fund basis (0.00165)		3,700
Depreciation, outlet works	50-year life, 3% sinking fund basis (0.00886)		800
Operation and maintenance			10,000
TOTAL -		$	105,500

ESTIMATED COSTS OF SUTHERLAND-SAN VICENTE PIPE LINE

(Based upon Prices Prevailing in April 1947)

Length: 13.5 miles.   Capacity: 45 second-feet.

From Mile	To Mile	Length in Miles	Type of Construction	Cost Per Mile	Cost Total	
0.0	2.40	2.40	36-inch diameter, reinforced concrete pipe	$ 57,000	$136,800	
2.40	2.90	0.50	6.5-foot diameter, concrete-lined tunnel	528,000	264,000	
2.90	3.25	0.35	36-inch diameter, reinforced concrete pipe	57,000	20,000	
3.25	3.55	0.30	30-inch diameter, reinforced concrete pipe	45,000	13,500	
3.55	4.55	1.00	30-inch diameter, reinforced concrete pipe	41,000	41,000	
4.55	5.00	0.45	36-inch diameter, reinforced concrete pipe	54,000	24,300	
5.00	7.50	2.50	36-inch diameter, concrete cylinder pipe	72,000	180,000	
7.50	13.50	6.00	36-inch diameter, reinforced concrete pipe	54,000	324,000	
Structures and valves					33,000	
Subtotal -						$1,036,600
Administration and engineering		10%				103,600
Contingencies		15%				155,500
Interest during construction		1 year at 3%				38,900
TOTAL -						$1,334,600

ANNUAL COST			
Interest	3%		$ 40,000
Amortization	50-year sinking fund at 3% (0.00886)		11,800
Depreciation	80-year life, 3% sinking fund basis (0.00312)		4,200
Operation and maintenance	0.15%		2,000
TOTAL -			$ 58,000

ESTIMATED COSTS OF PAMO RESERVOIR
WITH STORAGE CAPACITY OF 163,400 ACRE-FEET

(Based upon Prices Prevailing in April 1947)

Elevation of crest of dam:
  1,104 feet, U.S.G.S. datum.
Elevation of crest of spillway:
  1,084 feet.
Height of dam to spillway crest,
  above streerbed: 224 feet.

Capacity of reservoir to crest of
  spillway: 163,400 acre-feet.
Capacity of spillway with 5-foot
  freeboard: 44,000 second-feet.

Item	Quantity	Unit Price	Cost	
Dam				
Diversion and care of river		$ lump sum	$ 6,000	
Stripping and preparation of foundation				
Right abutment	264,000 cu.yds.	0.60	158,500	
Left abutment	68,600 cu.yds.	0.70	48,000	
Channel	343,000 cu.yds.	0.70	240,000	
Excavation, common				
From strip borrow	434,000 cu.yds.	0.30	130,000	
From borrow pits	7,226,208 cu.yds.	0.40	2,890,500	
Excavation, rock, from quarry	119,170 cu.yds.	3.00	359,000	
Embankment, compacted, from stockpile	262,000 cu.yds.	0.20	52,400	
Embankment, compacted, from borrow				
pits and spillway (earth-fill)	6,487,000 cu.yds.	0.15	972,000	$4,856,400
Spillway				
Excavation				
Common	48,600 cu.yds.	0.50	24,300	
Disintegrated rock	212,200 cu.yds.	0.75	159,000	
Rock	116,330 cu.yds.	3.00	490,000	
Rock, cutoff	1,275 cu.yds.	6.00	5,600	
Backfill	2,600 cu.yds.	0.40	1,000	
Concrete				
Mass				
Ogee weir	8,140 cu.yds.	11.00	89,500	
Retaining walls	6,348 cu.yds.	11.00	69,900	
Reinforced				
Spillway cutoff structure	1,801 cu.yds.	45.00	81,000	
Channel bottom paving	6,635 cu.yds.	25.00	165,500	
Channel side lining	1,700 cu.yds.	30.00	51,000	
Cutoff at ogee weir	1,275 cu.yds.	30.00	38,200	
Bridge	576 cu.yds.	50.00	28,800	
Drains		lump sum	14,700	
Pressure grouting	4,700 cu.yds.	2.00	9,400	1,227,900
Diversion Tunnel				
Excavation				
Common, open cut	13,300 cu.yds.	0.50	6,600	
Disintegrated rock, open cut	58,000 cu.yds.	0.75	43,500	
Rock, open cut	23,800 cu.yds.	3.00	71,400	
Tunnel	20,700 cu.yds.	15.00	310,500	
Concrete				
Mass, tunnel portals	610 cu.yds.	20.00	12,200	
Tunnel lining	4,770 cu.yds.	30.00	143,000	587,200
Outlet Works				
Excavation, rock	250 cu.yds.	6.00	1,500	
Concrete, for tower, reinforced	1,200 cu.yds.	60.00	72,000	
Concrete, for tunnel plug and connection	800 cu.yds.	25.00	20,000	
Cast iron, saucer valves and pipes	186,800 lbs.	0.25	46,700	
Miscellaneous iron and metal	15,000 lbs.	0.30	4,500	
Welded steel pipe, 36-inch diameter	406,000 lbs.	0.15	60,900	205,600
Reservoir				
Land and improvements	2,483 acres		128,000	
Relocating roads	3.25 miles	30,000	97,500	
Relocating truck trails	3.85 miles	15,000	57,800	
Clearing reservoir lands	2,150 acres.	25.00	53,700	337,000
Subtotal- -				$7,214,100
Administration and engineering	10% (0.10 x 7,214,100)			721,400
Contingencies on construction items	15% (0.15 x 7,086,100)			1,062,900
Interest during construction	1 year at 3%			270,000
TOTAL -				$9,268,400

ANNUAL COST			
Interest	3%		$ 278,100
Amortization	50-year sinking fund at 3% (0.00886)		82,100
Depreciation	100-year life, 3% sinking fund basis (0.00165)		14,600
Operation and maintenance			14,500
TOTAL -			$ 389,300

ESTIMATED COSTS OF PAMO CONDUIT
TO ACCOMMODATE RESERVOIR OF 163,400 ACRE-FOOT CAPACITY

(Based upon Prices Prevailing in April 1947)

Length: 36.3 miles.   Capacity: 30 second-feet.

From Mile	To Mile	Length in Miles	Type of Construction	Cost Per mile	Total	

From Mile	To Mile	Length in Miles	Type of Construction	Cost Per mile	Cost Total	
From Pamo Reservoir to filtration plant site: 19.6 miles						
0.0	12.1	11.1	39-inch diameter, reinforced concrete pipe	$ 63,190	$701,400	
6.2	6.5	0.3	39-inch diameter, concrete cylinder pipe	83,660	25,100	
8.4	9.1	0.7	39-inch diameter, concrete cylinder pipe	91,670	64,200	
12.1	12.9	0.8	6.5-foot diameter, concrete-lined tunnel	528,000	422,400	
12.9	19.6	6.2	39-inch diameter, concrete cylinder pipe	82,770	513,200	
13.7	14.2	0.5	39-inch diameter, concrete cylinder pipe	104,580	·52,300	
Structures and valves					48,900	$1,827,500
From filtration plant site to Chesterton Tank: 12.6 miles						
0.0	0.9	0.9	36-inch diameter, concrete cylinder pipe	93,500	84,200	
0.9	1.7	0.8	36-inch diameter, concrete cylinder pipe	139,000	111,200	
1.7	5.8	4.1	36-inch diameter, concrete cylinder pipe	93,500	383,300	
5.8	6.5	0.7	36-inch diameter, concrete cylinder pipe	139,000	97,300	
6.5	16.7	10.2	36-inch diameter, concrete cylinder pipe	84,500	861,900	
Structures and valves					40,000	1,577,900
Subtotal -						$3,405,400
Administration and engineering		10%				340,500
Contingencies		15%				510,800
TOTAL -						$4,256,700

ANNUAL COST

Interest	3%		$ 127,700
Amortization	50-year sinking fund at 3% (0.00886)		37,900
Depreciation	80-year life, 3% sinking fund basis (0.00312)		13,200
Operation and maintenance 0.10%			4,200
TOTAL -			$ 183,000

ESTIMATED COSTS OF LAKE HODGES
WITH STORAGE CAPACITY OF 310,000 ACRE-FEET

(Based upon Prices Prevailing in April 1947)

Elevation of crest of dam:
  410 feet, U.S.G.S. datum.
Elevation of crest of spillway:
  395 feet.
Height of dam to spillway crest,
  above streambed: 195 feet.

Capacity of reservoir to crest of
  spillway: 310,000 acre-feet.
Capacity of spillway:
  88,000 second-feet.

Item	Quantity	Unit Price	Cost	
Dam (including spillway)				
Diversion and care of river		$ lump sum	$ 25,000	
Excavation, rock	133,500 cu.yds.	3.50	467,300	
Concrete				
Mass	425,000 cu.yds.	10.50	4,462,500	
Spillway training walls and piers	2,920 cu.yds.	35.00	102,200	
Bridge and rail	570 cu.yds.	50.00	28,500	
Reinforcing steel	302,000 lbs.	0.10	30,200	
Grouting, drainage and seals	1,015 ft.of dam	150.00	152,200	$5,267,900
Outlets				
Reinforced concrete	100 cu.yds.	60.00	6,000	
Trash rack steel	55,000 lbs.	0.15	8,300	
36-inch diameter steel pipe	43,000 lbs.	0.20	8,600	
42-inch diameter steel pipe	33,000 lbs.	0.20	6,600	
Double disc valves, 36-inch diameter	6 each	3,500	21,000	
Slide gate, 3.5 x 3.5 feet	1 each	10,000	10,000	
Needle valve, 36-inch diameter	1 each	8,000	8,000	
Reinforcing steel	15,000 lbs.	0.10	1,500	70,000
Reservoir				
Land			1,782,000	
Relocating county and state roads	12 miles	20,000	240,000	
Clearing reservoir lands	2,000 acres	30.00	60,000	2,082,000
Subtotal -				$7,419,900
Administration and engineering	10% (0.10 x 7,419,900)			742,000
Contingencies on construction items	15% (0.15 x 5,637,900)			845,700
Interest during construction	1½ years at 3%			424,400
TOTAL -				$9,432,000
ANNUAL COST				
Interest	3%			$ 282,900
Amortization	50-year sinking fund at 3% (0.00886)			83,600
Depreciation, dam	100-year life, 3% sinking fund basis (0.00165)			11,400
Depreciation, outlet works	50-year life, 3% sinking fund basis (0.00886)			800
Operation and maintenance				14,500
TOTAL -				$ 393,200

ESTIMATED COSTS OF PUMPING WATER FROM LAKE HODGES
TO A POINT 2¼ MILES SOUTHEAST OF HODGES DAM
AT ELEVATION 650 FEET

(Based upon Prices Prevailing in April 1947)

	Lake Hodges Operated Alone				Lake Hodges Operated with Sutherland Reservoir						
					for Secondary Yield from Sutherland				for 1917-36 Firm Yield from Sutherland		
Storage capacity of Lake Hodges, in acre-feet	104,500	157,300	224,800	340,700	104,500	157,300	224,800	277,800	104,500	157,300	224,800
Average seasonal 1917-36 firm yield from Lake Hodges[a], in acre-feet	20,200	24,000	26,800	29,300	12,800	14,800	16,200	16,800	13,000	16,400	17,800
Average seasonal 1917-36 firm yield to City of San Diego from Lake Hodges, in acre-feet	12,000	15,800	18,600	21,100	4,600	6,600	8,000	8,600	4,800	8,200	9,600
Maximum demand[b], in second-feet	20.4	26.8	31.5	35.8	7.8	11.2	13.6	14.6	8.2	13.9	16.3
Installed pump capacity, in second-feet	25.5	33.5	39.4	44.7	9.7	14.0	17.0	18.2	10.3	17.4	20.4
Maximum pumping head, in feet	423	416	408	412	432	427	420	423	426	421	415
Average pumping head, in feet	341	327	313	298	351	335	321	311	349	334	318
Theoretical capacity[c], in horsepower	1,397	1,809	2,088	2,392	547	775	925	1,001	563	950	1,096
Installed capacity, in horsepower	1,750	2,260	2,610	2,990	680	970	1,160	1,250	700	1,190	1,370

Pipe line[d]	$263,800	$346,500	$435,100	$435,100	$180,000	$204,600	$236,000	$236,000	$180,000	$236,000	$263,800
Pumping plant											
Pumps	11,200	11,800	12,300	12,700	6,400	8,800	9,700	10,000	6,900	10,500	10,300
Fittings, valves and meters	21,000	24,300	25,800	27,200	7,800	12,000	14,600	16,000	8,500	14,900	17,600
Motors	10,600	13,200	14,900	16,800	4,600	6,500	7,500	8,000	5,100	7,700	8,700
Switchboards, controls, meters	10,500	10,500	10,500	10,500	10,500	10,500	10,500	10,500	10,500	10,500	10,500
Building	29,000	32,000	35,000	38,000	17,000	20,000	23,000	26,000	17,000	23,000	27,000
House and grounds	12,000	12,000	12,000	12,000	12,000	12,000	12,000	12,000	12,000	12,000	12,000
Engineering and administration, 10%	9,400	10,400	11,100	11,700	5,800	7,000	7,700	8,200	6,000	7,900	8,600
Contingencies, 15%	14,100	15,600	16,600	17,600	8,700	10,500	11,600	12,400	9,000	11,800	12,900
TOTALS	$381,600	$476,300	$573,300	$581,600	$252,800	$291,900	$332,600	$339,100	$255,000	$334,300	$371,400

ANNUAL COSTS											
Pipe line[e]	$ 12,200	$ 16,100	$ 20,300	$ 20,300	$ 8,100	$ 9,500	$ 10,800	$ 10,800	$ 8,100	$ 10,800	$ 12,200
Pumping plant[e]	13,400	14,200	14,800	15,400	10,200	11,600	12,300	12,800	10,600	12,500	13,200
Energy cost[f]	50,600	63,700	71,700	76,300	20,600	27,800	31,200	33,400	21,300	34,200	38,000
Power demand charge	10,100	12,200	13,500	14,200	4,800	6,300	7,100	7,300	5,000	7,400	8,100
TOTALS	$ 86,300	$106,200	$120,300	$126,200	$ 43,700	$ 55,200	$ 61,400	$ 64,300	$ 45,000	$ 64,900	$ 71,500
Annual costs per acre-foot	$ 7.19	$ 6.72	$ 6.46	$ 5.98	$ 9.51	$ 8.37	$ 7.68	$ 7.48	$ 9.38	$ 7.91	$ 7.44
Annual costs per acre-foot per foot of pumping head	.021	.021	.021	.020	.027	.025	.024	.024	.027	.024	.023

Notes:

a - Based on preliminary yield studies, which differ slightly from final results.
b - Maximum demand assumed as average rate during July. July total equals 10.44 per cent of seasonal.
c - Overall plant efficiency assumed as 70 per cent.
d - Includes engineering and administration item of 10 per cent, and 15 per cent for contingencies.
e - Includes interest at 3 per cent, and charges for amortization, depreciation, operation and maintenance.
f - Based on rate schedule P-2, with oil at $1.45 per barrel.

ESTIMATED COSTS OF MISSION GORGE RESERVOIR NO. ZERO

(Based upon Prices Prevailing in April 1947)

Elevation of crest of dam:
 353 feet, U.S.G.S. datum.
Elevation of crest of spillway:
 336 feet.
Height of dam to spillway crest,
 above streambed: 58 feet.

Capacity of reservoir to crest of
 spillway: 23,700 acre-feet.
Capacity of spillway:
 116,500 second-feet.

Item	Quantity	Unit Price	Cost	
Concrete Gravity Dam (including spillway)				
Diversion and care of river		$ lump sum	$ 25,000	
Excavation				
Common	26,000 cu.yds.	1.50	39,000	
Rock, stripping	31,700 cu.yds.	3.00	95,100	
Cutoff trenches	3,300 cu.yds.	8.00	26,400	
Concrete				
Mass	69,200 cu.yds.	10.50	726,600	
Reinforced				
Gate house pier	130 cu.yds.	30.00	3,900	
Spillway training walls	240 cu.yds.	30.00	7,200	
Intake tower and gate house	140 cu.yds.	60.00	8,400	
Reinforcing steel	44,000 lbs.	0.10	4,400	
Grouting, drainage and seals	850 lin. ft. of dam	125.00	106,300	$1,042,300
Earth Fill Dam				
Excavation				
Common, stripping	28,900 cu.yds.	1.00	28,900	
Borrow pit, and haul	116,500 cu.yds.	0.45	52,400	
Embankment	101,300 cu.yds.	0.15	15,200	
Riprap				
Rock	13,263 cu.yds.	2.00	26,500	
Gravel	2,738 cu.yds.	2.00	5,500	128,500
Outlets				
Steel pipe, 30-inch diameter	310 lin. ft.	15.00	4,600	
Slide valves in pipes, 30-inch diameter	3 each	2,800	8,400	
Slide valves in tower, 30-inch diameter	3 each	2,800	8,400	
Trash rack hoist	1 each	700.00	700	
Trash rack and guides	6,400 lbs.	0.15	1,000	23,100
Reservoir				
Land and improvements	2,268 acres		911,700	
Relocating roads	3.9 miles		167,500	
Relocating pipe line	3.93 miles	90,000	353,700	
Clearing reservoir lands	480 acres	30.00	14,400	1,447,300
Subtotal -				$2,641,200
Administration and engineering	10% (0.10 x 2,641,200)			264,100
Contingencies on construction items	15% (0.15 x 1,729,500)			259,400
Interest during construction	9 months at 3%			72,800
TOTAL -				$3,237,500

ANNUAL COST				
Interest	3%			$ 97,000
Amortization	50-year sinking fund at 3% (0.00886)			28,700
Depreciation, dam	100-year life, 3% sinking fund basis (0.00165)			2,500
Depreciation, outlet works	50-year life, 3% sinking fund basis (0.00886)			300
Operation and maintenance				7,600
TOTAL -				$ 136,100

ESTIMATED COSTS OF MISSION GORGE RESERVOIR NO. 2

(Based upon Prices Prevailing in April 1947)

Elevation of crest of dam:
353 feet, U.S.C.S. datum.
Elevation of crest of spillway:
336 feet.
Height of dam to spillway crest,
above streambed: 92 feet.

Capacity of reservoir to crest of
spillway: 29,200 acre-feet.
Capacity of spillway:
116,500 second-feet.

Item	Quantity	Unit Price	Cost	
Concrete Gravity Dam (including spillway)				
Diversion and care of river		¢ lump sum	$ 25,000	
Excavation				
Common	14,160 cu.yds.	1.50	21,200	
Rock, stripping	30,130 cu.yds.	3.00	90,400	
Cutoff trenches	3,920 cu.yds.	8.00	31,400	
Outlet tunnel	90 cu.yds.	20.00	1,800	
Concrete				
Mass				
In dam	85,950 cu.yds.	10.50	902,500	
Outlet tunnel backfill	70 cu.yds.	20.00	1,400	
Reinforced				
Spillway walls	330 cu.yds.	35.00	11,500	
Spillway lining	1,010 cu.yds.	31.00	31,300	
Gate tower and house	100 cu.yds.	60.00	6,000	
Gate house pier	140 cu.yds.	30.00	4,200	
Reinforcing steel	151,000 lbs.	0.10	15,100	
Grouting, drainage and seals	640 ft.of dam	150.00	96,000	
Backfill	4,100 cu.yds.	0.50	2,100	$1,239,900
Outlets				
Steel pipe, 30-inch diameter	460 lin. ft.	15.00	6,900	
Trash racks and guides	6,400 lbs.	0.15	1,000	
Slide valves in pipes, 30-inch diameter	3 each	2,800	8,400	
Slide valves in tower, 30-inch diameter	3 each	2,800	8,400	
Trash rack hoist	1 each	700.00	700	25,400
Reservoir				
Land and improvements	2,268 acres		911,700	
Relocating roads	5.0 miles		297,000	
Relocating pipe line	4.48 miles	90,000	403,200	
Clearing land	500 acres	30.00	15,000	1,626,900
Subtotal -				$2,892,200
Administration and engineering	10% (0.10 x 2,892,200)			289,200
Contingencies on construction items	15% (0.15 x 1,980,500)			297,100
Interest during construction	1 year at 3%			107,600
TOTAL -				$3,586,100

ANNUAL COST				
Interest	3%			$ 107,600
Amortization	50-year sinking fund at 3% (0.00886)			31,800
Depreciation, dam	100-year life, 3% sinking fund basis (0.00165)			2,600
Depreciation, outlet works	50-year life, 3% sinking fund basis (0.00886)			300
Operation and maintenance				7,700
TOTAL -				$ 150,000

ESTIMATED COSTS OF MISSION GORGE RESERVOIR NO. 3

With Concrete Gravity Dam at Lower Site

(Based upon Prices Prevailing in April 1947)

Elevation of crest of dam:
331 feet, U.S.G.S. datum.
Elevation of crest of spillway
316 feet.
Height of dam to spillway crest,
above streambed: 216 feet.

Capacity of reservoir to crest of
spillway: 29,200 acre-feet.
Capacity of spillway,
131,000 second-feet.

Item	Quantity	Unit Price	Cost	
Concrete Gravity Dam (including spillway)				
Diversion and care of river		$ lump sum	$ 25,000	
Excavation				
Common	46,200 cu.yds.	1.50	69,300	
Rock, stripping	93,500 cu.yds.	3.00	280,500	
Cutoff trenches	4,100 cu.yds.	8.00	32,800	
Concrete				
Mass, dam	279,900 cu.yds.	10.00	2,799,000	
Reinforced				
Spillway walls	230 cu.yds.	35.00	8,100	
Spillway lining	6,270 cu.yds.	30.00	188,100	
Reinforcing steel	517,700 lbs.	0.10	51,800	
Grouting, drainage and seals	900 ft.of dam	150.00	135,000	
Backfill	8,250 cu.yds.	0.50	4,100	$3,593,700
Outlets				
Excavation, outlet tunnel	450 cu.yds.	20.00	9,000	
Concrete				
Mass, outlet tunnel backfill	370 cu.yds.	20.00	7,400	
Reinforced				
Gate tower and house	370 cu.yds.	60.00	22,200	
Gate house pier	200 cu.yds.	30.00	6,000	
Reinforcing steel	104,100 lbs.	0.10	10,400	
Trash rack and guides	19,500 lbs.	0.15	2,900	
Slide valves in pipes, 30-inch diameter	3 each	2,800	8,400	
Slide valves in tower, 30-inch diameter	5 each	2,800	14,000	
Trash rack hoist	1 each	700.00	700	
Steel pipe, 30-inch diameter	800 lin. ft.	15.00	12,000	93,000
Reservoir				
Land and improvements	1,202 acres		211,200	
Relocating roads	6.35 miles		341,500	
Relocating pipe line	6.00 miles	90,000	540,000	
Clearing land	800 acres	30.00	24,000	1,116,700
Subtotal -				$4,803,400
Administration and engineering	10% (0.10 x 4,803,400)			480,300
Contingencies on construction items	15% (0.15 x 4,592,200)			688,800
Interest during construction	1 year at 3%			184,700
TOTAL -				$6,157,200
ANNUAL COST				
Interest	3%			$ 184,700
Amortization	50-year sinking fund at 3% (0.00886)			54,600
Depreciation, dam	100-year life, 3% sinking fund basis (0.00165)			7,600
Depreciation, outlet works	50-year life, 3% sinking fund basis (0.00886)			1,100
Operation and maintenance				11,000
TOTAL -				$ 259,000

ESTIMATED COSTS OF MISSION GORGE RESERVOIR NO. 3

With Concrete Variable-Radius Arch Dam at Lower Site

(Based upon Prices Prevailing in April 1947)

Elevation of crest of dam:
 331 feet, U.S.G.S. datum.
Elevation of crest of spillway:
 316 feet.
Height of dam to spillway crest,
 above streambed: 216 feet.

Capacity of reservoir to crest of
 spillway: 29,200 acre-feet.
Capacity of spillway:
 131,000 second-feet.

Item	Quantity	Unit Price	Cost	
Concrete Arch Dam (including spillway)				
Diversion and care of river		$ lump sum	$ 25,000	
Excavation				
Rock, stripping	98,600 cu.yds.	3.00	295,800	
Spillway apron cutoff	1,200 cu.yds.	8.00	9,600	
Concrete				
Arch, gravity section and thrust block	133,000 cu.yds.	16.00	2,128,000	
Spillway apron	14,800 cu.yds.	15.00	222,000	
Spillway apron cutoff	1,200 cu.yds.	20.00	24,000	
Training walls	700 cu.yds.	35.00	24,500	
Parapet wall	150 cu.yds.	33.00	5,000	
Reinforcing steel	80,000 lbs.	0.10	8,000	
Metal water stops, adjustment joints	12,100 lbs.	1.50	18,200	
Sliding joint				
Service sheet	16,000 sq.ft.	0.30	4,800	
Metal water stop	360 lin.ft.	4.00	1,400	
Grouting	1,000 ft.of dam	150.00	150,000	$2,916,300
Outlets				
Excavation, rock	150 cu.yds.	8.00	1,200	
Concrete				
Manifold casing	150 cu.yds.	40.00	6,000	
Trench	110 cu.yds.	25.00	2,700	
Reinforcing steel	20,000 lbs.	0.10	2,000	
Trash racks	10,000 lbs.	0.20	2,000	
Gate valve, 36-inch diameter	1 each	3,000	3,000	
Hydraulically operated valves, 30-inch diameter	5 each	6,000	30,000	
Steel pipe, 36-inch diameter	360 lin.ft.	16.00	5,800	
Copper pipe, 3/4-inch diameter	5,500 lin.ft.	0.60	3,300	
Gate houses	2 each	lump sum	4,000	60,000
Reservoir				
Land and improvements	1,202 acres		211,200	
Relocating roads	6.35 miles		341,500	
Relocating pipe line	6.00 miles	90,000	540,000	
Clearing land	800 acres	30.00	24,000	1,116,700
Subtotal -				$4,093,000
Administration and engineering	10% (0.10 x 4,093,000)			409,300
Contingencies on construction items	15% (0.15 x 3,881,800)			582,300
Interest during construction	1 year at 3%			157,300
TOTAL -				$5,241,900

ANNUAL COST

Interest	3%	$	157,300
Amortization	50-year sinking fund at 3% (0.00886)		46,400
Depreciation, dam	100-year life, 3% sinking fund basis (0.00165)		4,800
Depreciation, outlet works	50-year life, 3% sinking fund basis (0.00886)		500
Operation and maintenance			11,000
TOTAL -		$	220,000

ESTIMATED COSTS OF ENLARGEMENT OF SAN VICENTE RESERVOIR

To Capacity of 250,000 Acre-feet

(Based upon Prices Prevailing in April 1947)

Elevation of crest of dam:
777 feet, U.S.G.S. datum.
Elevation of crest of spillway:
768 feet.
Height of dam to spillway crest,
above streambed: 308 feet.

Capacity of reservoir to crest of
spillway: 250,000 acre-feet.
Capacity of spillway:
42,000 second feet.

Item	Quantity	Unit Price	Cost	
Concrete Gravity Dam Enlargement				
Temporary outlet works		$ lump sum	$ 5,000	
Excavation				
Common	22,000 cu.yds.	1.50	33,000	
Rock, stripping	46,000 cu.yds.	3.00	138,000	
Preparation of foundation for concrete	9,900 sq.yds.	2.00	19,800	
Concrete				
Mass	620,000 cu.yds.	10.00	6,200,000	
Reinforced				
Outlet tower and house	252 cu.yds.	60.00	15,100	
Spillway training walls	310 cu.yds.	35.00	10,900	
Crest parapet walls	300 cu.yds.	30.00	9,000	
Reinforcing steel	109,000 lbs.	0.10	10,900	
Preparation of surface of existing dam	16,000 sq.yds.	4.00	64,000	
Removal of existing concrete			5,000	
Grouting, drainage and seals				
Percussion grout holes	500 lin.ft.	1.00	500	
Rotary grout holes	1,000 lin.ft.	3.00	3,000	
Grout	500 cu.ft.	2.00	1,000	
Copper water seals	3,400 lin.ft.	2.00	6,800	
Vertical and inclined drains	23,000 lin.ft.	1.00	23,000	
Rotary drain holes	900 lin.ft.	3.00	2,700	$6,547,700
Outlets				
Cast iron pipe, 36-inch diameter	300 lin.ft.	18.00	5,400	
Saucer valves	25,000 lbs.	0.20	5,000	
Miscellaneous metal work	20,000 lbs.	0.50	10,000	
Valve house reconstruction		lump sum	5,000	25,400
Reservoir				
Clearing reservoir land	490 acres	30.00	14,700	14,700
Subtotal -				$6,587,800
Administration and engineering	10% (0.10 x 6,587,800)			658,800
Contingencies on construction items	15% (0.15 x 6,587,800)			988,200
Interest during construction	1 year at 3%			254,700
TOTAL -				$8,489,500
ANNUAL COST				
Interest	3%			254,700
Amortization	50-year sinking fund at 3% (0.00886)			74,200
Depreciation, dam	100-year life, 3% sinking fund basis (0.00165)			10,800
Depreciation, outlet works	50-year life, 3% sinking fund basis (0.00886)			200
Operation and maintenance				12,700
TOTAL -				$ 352,600